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CHANGE ORDERS - IDENTIFYING KEY FACTORS AND THEIR IMPACT ON CONSTRUCTION PROJECTS

by

ROSCOE DILLARD GEORGE III

B.S.C.E. Purdue University
(1977)

Submitted to the Department of
Civil Engineering
in Partial Fulfillment of the
Requirements of the
Degree of

MASTER OF SCIENCE IN CIVIL ENGINEERING

at the

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

September 1982

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ROSCOE DILLARD GEORGE III

Submitted to the Department of Civil Engineering on 20 August 1982 in partial fulfillment of the requirements for the Degree of Master of Science in Civil Engineering

ABSTRACT

A case study was conducted on six building construction projects belonging to two owner organizations, the U.S. Navy and M.I.T., to investigate change orders. The same type of facilities within the two organizations were selected for comparison, to examine similarities and differences in change orders, across types of facilities and owner organizations. The project files were reviewed in depth and a list made of changes to the contract. Pertinent information including the reason for the change, the type of work, and the initiator was collected for each change to develop a better understanding of change orders. Then an interview with the owner's project manager was conducted to identify significant changes and to discuss the factors that made them significant.

Using the data gathered from the six projects, an analysis of change order characteristics was performed by examining the type of contract, type of construction, cost and time to complete, reason for the change and type of work. General trends were identified within each organization and type of facility, and the influencing factors leading to these trends were discussed. The influencing factors were divided into three categories which were an indication of the project participants' level of control over them. These categories were organizational characteristics, project characteristics and external conditions. A model was then developed relating the influencing factors to the major types of changes observed on the projects.

It was found that organizational characteristics contributed to most of the changes overall, but that a disproportionate number of significant changes resulted

from project characteristics and external conditions. The major types of changes included design errors or omissions, customer requests and unforeseen conditions.

Thesis Supervisor: Dr. Henry G. Irwig

Title: Associate Professor of Civil Engineering

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PREFACE

AND

ACKNOWLEDGEMENTS

In the research for this thesis I have tried to examine a problem that is common in construction, that of change orders, in an attempt to gain some insight into possible solutions for better contract administration. As I began, my intent was to develop a rational and objective framework in which to classify change orders, in the hope that some specifically identifiable characteristics would emerge, by which significant changes could be identified. What I discovered instead was that change orders are the result of an ever changing and complex set of factors that make up the project process. It became apparent that change orders could not be examined in isolation, but had to be understood in relation to the system which produces them. I found that changes in construction are unique occurrences, and as such, statistical analysis and categorization is useful only for identifying general trends. I hope that by identifying these general trends and discussing what I believe the underlying causes to be, that a better understanding of the project process can be developed. In contract administration, change orders should be seen as a symptom, not a cause. They can be an indication of potential problem areas, and are thus useful in identifying areas that could be improved. Hopefully, this study will benefit those who work with change orders, not because it says anything that is really new, but because it may help to put in perspective what is already known.

There are numerous debts of thanks that I owe for the assistance received in completing this work. First and foremost I wish to thank the Lord who used my time at M.I.T. and the writing of this thesis to mature my relationship with Him and to strengthen my faith. God led me to many individuals who assisted me in the work that is contained herein, and I would also like to acknowledge their contribution.

I wish to thank Professor Irwig, my advisor, for the guidance and encouragement that he provided during the difficult and frustrating moments associated with the

writing of this thesis. The insight he provided shed light on areas that were unclear and his guidance opened up paths when it seemed that only dead ends existed. Throughout this work he encouraged me and required me to do nothing less than my best, and for that I am grateful.

I want to express my gratitude to the U.S. Navy and the Civil Engineer Corps for the opportunity to study at M.I.T. The assistance of members of the Naval Facilities Engineering Command is also greatly appreciated. Special thanks are extended to the following people who graciously assisted me in this research. At the OICC, Trident office in King's Bay, Georgia, CAPT. W. C. CONNOR, CAPT. J. M. GREENWALD, LCDR. L. L. ANDERSON, Mr. L. NELSON, Mr. W. HOYER, and Mr. E. TAYLOR. At the ROICC office in Orlando, Florida, LCDR. J. M. KEIFER, Mr. B. BLAIS, and Mr. P. HALEY. At the ROICC office in New London, Connecticut, LCDR. H. B. ST. PETER and Mr. E. REELITZ.

For their invaluable assistance and willingness to take time out of their busy day, I want to especially thank Mr. Harry Portnoy, the Director of Architecture, Engineering and Construction Services at M.I.T., along with Mr. Bill Combs, Ms. Fay DeAvignon and Mr. Bill Tibbs of his staff. These individuals spent a great deal of time and demonstrated admirable patience in helping me to understand the M.I.T. project process and the jobs that I examined. I would also like to thank Mr. John Stetson of Turner Construction Company for the time he took to allow me an interview and provide some insight into the contractor's perspective.

Last, but certainly not least, I want to express my gratitude to M.I.T. Although I have gained new insights into principles of modern technology and developed new techniques of analysis, these are not the main benefit I leave with. My time at M.I.T. was a period that stretched me to the full extent of what I could do and at times past. There were times of frustration and times of disillusionment, but as a result of this I was able to more closely examine myself and more clearly than ever see my need for God. My prayer for every student at M.I.T. is that they would leave, not feeling that they have all the answers or even that man alone is able to solve all this world's problems; but that they realize that man's knowledge is a gift from God and that only through the use of this gift in the right relationship with the Creator, is there any hope that our endeavors here will be fruitful.

"Trust in the Lord with all your heart, And do not lean on your own understanding."

(Proverbs 3:5, New American Standard)

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CHAPTER 1

CHANGE ORDERS, WHAT ARE THEY?

INTRODUCTION

The timely and cost effective completion of construction projects depends to a large extent on successful contract administration. A major problem in construction contracts is the managing of change orders and their resulting impact on projects. This research is concerned with examining change orders to get a better understanding of what they are and why they occur. The focus of the study is to identify the causes of changes to construction contracts, problems encountered in administering these changes and key factors relating the source of changes and their impact on projects. A discussion of influencing factors contributing to changes, and characteristics that identify a contract change as significant, will be presented in an effort to help contract administrators reduce the adverse effect change orders can have on a project.

It is necessary to develop a non-partisan definition of change orders to objectively examine the nature of contract changes and their impact. It should be noted

that "change orders" are often an arbitrary collection of contract "changes." This study reviews change orders on six projects, specifically examining each contract change. A contract change for the purpose of this research has been defined as any modification to the project definition as originally agreed to between the owner and the contractor. In practice, there are disagreements and disputes over what constitutes a change to the contract. As a result of the different objectives, motivations, responsibilities and understanding of the parties involved, a precise and unambiguous working definition of a change order does not exist. However, it is important to gain a clear understanding of contract changes and why they occur, because litigation, cost and time overruns, and losses often result from disputes and misunderstandings over change orders.

Although most, if not all, contract administrators would agree that change orders are a major consideration in construction, there has not been much research specifically in the area of contract changes. Much of what has been written on change orders discusses how to process them, formats and procedures to use in administering them, how to evaluate their impact in terms of cost and time, and warnings to both the owner and contractor on how to protect themselves from claims by the other party. It

appears that a detailed analysis of contract changes has not been done. In an effort to encourage greater cooperation between the parties involved in construction, this study seeks to develop a clearer understanding of the nature of contract changes and to propose a classification system by which they can be better understood.

Too often the attitude is taken that changes are inevitable in construction (and no doubt they are), but little or no consideration is given to the impact of changes on the overall project and the members involved. Discussions with project managers reveal that there are specifically identifiable change orders on most projects that are "significant or important." This research attempts to define significant change orders and characteristics that identify them, and to examine in what respect significant changes are similar and different on various projects. By identifying these factors, hopefully, contract administrators will be able to reduce the number of change orders required and their impact on construction projects.

CASE STUDY APPROACH

When deciding on the method of study to utilize for this research, several alternatives were reviewed. After examining the advantages and disadvantages of an in-depth

study of one project, interview of project managers and a survey of contractor/owner organizations, the case study approach was selected. The major reason for selecting the case study method was that very little previous research had been done on change orders and no framework existed for developing an objective format for a questionnaire or interview. The case study was structured to incorporate some of the strengths of the alternative methods into the approach.

The advantage of doing an in-depth study of a single project is the familiarity with the project circumstances and the level of detail it offers. It was felt this objective could be met by selecting a small number of projects to allow a detailed case study of each one. The interview technique offers the advantage of drawing on the project manager's experience and knowledge of the project. To gain this insight, an interview was conducted with the owner's project manager after each project file had been reviewed and a list of contract changes compiled. By waiting until the end, specific information gathered was discussed in an effort to draw out new insights into the problem of change orders.

A case study of each project was conducted in the following manner. First, the project files were reviewed, paying particular attention to the original contract,

correspondence pertaining to changes, and change order documents. A list of contract changes was compiled and specific information (discussed in Chapter 2) was collected on each change. Once an overview of the changes had been completed, an interview was held with the owner's project manager. During this interview information that was not identified by the search through the project file was gathered and the project manager's assessment of significant changes was discussed.

Six projects were selected for case study, three U.S. Navy projects and three M.I.T. projects. To achieve consistency in the data the research was limited to U.S. building construction within two owner organizations. The projects were selected because of access to pertinent information and comparability of facilities. The following three pairs of similar projects were chosen.

1) Classroom Building:
   a) Applied Instruction Building, Naval Training Center, Orlando, Florida ($3,857,000)
   b) Alterations and Renovations to Building E-51, M.I.T., Cambridge, Massachusetts ($3,664,937.41)
2) Dormitory Building:
   a) 600 Person Unaccompanied Enlisted Quarters (UEQ), Naval Submarine Base, New London, Connecticut ($7,600,000)
   b) 500 Memorial Drive (Next House), M.I.T., Cambridge, Massachusetts ($8,597,300)
3) Hospital:
   a) Hospital Replacement, NRMC, Naval Training Center, Orlando, Florida ($16,770,000)

b) College of Health Sciences, Technology & Management and Health Services Building (HSTM/HS), M.I.T., Cambridge, Massachusetts ($24,835,000)

A brief description of each project is included in Chapter 3.

OBJECTIVES OF THE RESEARCH

By looking at these projects, similarities and differences between change orders, across types of facilities and owner organizations, can be examined. Both owner organizations are bureaucratic in nature and non-profit. For this reason their financial objectives and motivational incentives are somewhat different from profit oriented firms. Both M.I.T. and the Navy have in-house design and architectural services available; this places them in a category of "informed owner." Although non-profit organizations represent a select group of owners, perhaps small in number, they perform a large percentage of the value of construction in the United States. Public construction alone accounted for approximately 25% of work in place in 1980; and if private religious facilities, educational facilities, and hospitals and institutions are included, they make up approximately 27% of 1980 work in place. (Construction Review, U.S. Department of Commerce) The conclusions of this research may be limited by the nature of the projects investigated, but the meth-

odology and general framework developed should be applicable to other types of construction and different owner organizations.

Initially, the ultimate objective of this research was to develop a classification system for change orders which could be used in a predictive fashion to identify major changes on a project. The finding however, was that change orders were an end product of the interaction of a complex set of project factors. By identifying key factors on the projects reviewed, and relating them to the types of changes observed, a framework for classifying change orders was proposed. This framework can be used to identify potential organizational and industry weaknesses. After isolating problem areas in the project process, solutions can be developed to improve the process and thereby reduce the number of change orders and their impact on construction.

OUTLINE OF REMAINING CHAPTERS

The remaining chapters will develop the basis for a change order classification system by discussing in detail the approach used to gather data and the conclusions drawn from the investigation. Chapter 2 reviews the work that has been done in the areas of contract administration and change orders in construction; and describes the

information gathered in this research and the procedure for data collection. Chapter 3 reviews each project and their significant events, and examines the major factors influencing changes on the project. In Chapter 4 the two owner organizations are compared and the characteristics of major categories of changes reviewed. Reasons for similarities and differences in the characteristics of major changes between the owner organizations are proposed and their significance discussed. In Chapter 5 a model is developed to visualize how change orders occur on construction projects. Then the conclusions of this research are discussed along with applications for the construction industry. Areas of further research are also suggested.

CHAPTER 2

COLLECTING THE DATA

INTRODUCTION

There is widespread agreement that change orders are a significant factor in construction contracting, but there is much less agreement as to why. In fact disputes and claims arising from changes in the contract are one of the most significant causes of increased costs, extended durations and losses for both the owner and contractor in construction. Everyone experienced in the construction contracting process would acknowledge that change orders are inevitable and are to be expected, but most would also agree that there are steps that can be taken to prevent or reduce the adverse effects of changes.

Change orders are an integral part of construction contracting and most of the literature that discusses contract changes is in the related area of contract administration. Construction contracting has been examined from three major perspectives, organizational, legal and risk, by parties concerned with improving the construction process. There are common components in each of these

areas of study that form the basic considerations in contract administration.

The study of organizational structure examines the parties involved in the construction process and defines the roles and responsibilities of each member. The interaction and relationships between these members are observed under changing conditions of authority, responsibility, and environmental and organizational characteristics. The conclusions from these studies are used to develop theories on how to structure organizations in a manner which is suited to the situation in which they function.

Traditionally the roles of the owner, architect and contractor were generally stable in building construction, and as a result of this they were well defined and understood. With the advent of new contractual agreements, there are now a variety of roles assigned to the key participants in a project. Due to the increasing magnitude and complexity of constructed facilities and the changing roles of the parties involved, there has been an increase in disputes and disagreements on construction projects. As a result of this, the legal aspects of construction contracting have gained significant importance.

There is a variety of literature on the legal aspects of construction. Topics discussed include court precedence and what the generally established obligations and responsibilities are for the different parties under specific types of contracts and conditions. The selection of contract type, in light of the advantages and disadvantages of each, are discussed along with detailed analysis of various contract clauses, their interpretations and when they should be utilized. Procedural steps to be taken for notification of changes, standard forms suggested for use, and procedures for processing change orders are also presented. The types of information that should be recorded in project files, both for the contractor and the owner, are discussed in the context of how to use this documentation in the event of disputes and claims. Methodologies for calculating the impact of change orders in terms of cost and time analysis are suggested, accounting not only for the direct impact on cost and time, but also for the indirect impact, which is less well defined.

Risk allocation is a newer field of study which seeks to identify areas of risk and determine how to best manage different types of risk. Risk categories are being defined, along with the development of methods for allocation of risk, which seek to reduce the cost

and impact that different types of risk have on projects. By examining the goals, expertise and financial stability of the parties involved in construction, assignment of risk is based on the members' ability to manage the risk, both in terms of technological and financial capabilities. Utility theory is applied to quantify the participants' "risk averseness" and determine the resulting incremental cost of risk assignment. Then the most economical allocation of risk for a particular project can theoretically be determined. The central concept is that risk should be assigned to those who can best manage and control the risk, and that equitable compensation is due to the party who assumes such risk.

RELATED STUDIES

Very little has been written specifically on change orders; and what has been published is generally a procedural approach on how to process change orders and what documentation is recommended to protect the different parties in the event of a dispute. There are two specific studies that have been done in the related areas of delays and time extensions in construction. The first was a survey of general contractors, architects and engineers to determine the viewpoint of each group as to what the

major sources of delay are in construction.[1] There are several interesting findings that resulted from this research which relate to this report. First, the amount of agreement between the three parties, as measured in the study, showed that there was more agreement between architects and engineers than between contractors and engineers, and the least amount of agreement was between contractors and architects. In many areas there was general agreement between all three parties, however, one of the categories of greatest disagreement was that of design changes. The severity of design changes was ranked very high by contractors, and not nearly as important by architects and engineers. The study concludes that this is a result of the lack of control the contractor has over design changes. This points out the difference of perspective these groups have, which can affect their interaction on projects. Another interesting and significant finding of this study was that factors not included on the survey were considered important by nearly 30% of those responding. These factors included, "labor-management relations and strikes; poor organization, scheduling and coordination; deteriorating quality of workmanship and productivity; lack of skill in craftsmen and the quality of training; delivery delays; and the high cost

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1. "Causes of Delay in the Construction Industry," Journal of the Construction Division, ASCE, November 1971.

of financing." It should be noted that almost all of these areas were related to organizational characteristics.

The second study categorized time extensions on military construction projects according to extension type, for different types of facilities. Design problems proved to be a major category on most of the facility types examined.[2]

From these two studies it is clear that design changes are a significant factor in construction. In addition, the first study suggested that the interaction of organizations and organizational characteristics were considered important by a high percentage of those polled, even though these factors were not listed on the survey.

DEFINITION OF CHANGES AND CHANGE ORDERS

In order to get a better understanding of change orders and changes to construction contracts, an exact definition of what constitutes both a change order and a contract change, needs to be developed. The following definitions are submitted for amplification.

> "When additions, deductions, or changes in the work are made by the owner, a supplement to

---

2. "Construction Time Overruns," Technical Report P-16, CERL, August 1973.

the contract between the owner and the prime contractor is prepared that can be on the basis of a lump sum, unit-prices, or a cost-plus arrangement. This supplement, called a "change order," is consummated by a written instrument that describes the modification to be made, the change in the contract amount, and any authorized extension of contract time." (Construction Contracting, Richard H. Clough, p. 132)

"A change order is a document that is added to the construction documents after award of a contract to clarify, revise, add to, or delete from the previous requirements." (CSI Manual of Practice, Project Manual: Procedures & Techniques, Construction Specifications Institute, p. 9/4)

The definition for a change to a construction contract, as given in the Naval School Civil Engineer Corps Officers student guide, Construction Contract Modifications is,

"an assertion by either party that the work required by the owner, or the conditions of the work encountered by the contractor are different from those specified by the contract."

". . . changes might involve additions to or deletions from the contract, modifications of the work, changes in the methods or manner of work performance, changes in owner-provided materials or facilities, or even changes in contract time requirements. Changes may have to be made to correct errors in the drawings or specifications. Owner requirements and circumstances sometimes change after the contract award, and changes must be made to meet such conditions. Changes are even occasionally made as the result of suggestions by the contractor." (Construction Contracting, Richard H. Clough, p. 128)

The key concepts from these definitions are that a change involves all or some of the following:

1) an addition, deduction or change to the work,
2) an assertion by either party (contractor or owner),
3) the work required by the owner has changed,

4) the conditions of the work encountered by the contractor have changed,

5) clarifies or revises project requirements.

The key concepts of a change order include those of the change, and in addition it is:

1) a supplement to the contract,

2) a written instrument describing modifications,

3) an amendment to the contract amount and time when required, and

4) a settlement reached between the owner and contractor after the award of the construction contract.

A change therefore, is any modification to the project definition, as originally agreed to between the owner and contractor. A change order is a formal document, setting forth in writing the terms of a change or changes, as agreed to between the owner and contractor.

Prior to negotiations between the owner and contractor changes are typically referred to as "proposed changes," "prospective changes" or "change estimates," depending on the individual organization. "Some offices wait until a number of proposed changes and change order proposals have accumulated before writing a change order covering all of them. The number may be arbitrary or based on the amount of time or money involved -- five changes per change order, or $1,000 worth of changes."[3]

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3. CSI Manual of Practice, Project Manual: Procedures & Techniques, Construction Specifications Institute, p. 9/4.

In addition to examining change orders, claims submitted by the contractor were also reviewed. There is not a clear distinction between claims and change orders, since a claim will become a change order if both the owner and the contractor (or a mutually recognized third party) decide that additional money and/or time is due as a result of a change to the contract. Claims generally involve an area of dispute between the owner and contractor, and can therefore be a detriment to the project.

DATA COLLECTION

At the beginning of this research a change order flow diagram was developed to establish a framework in which to conduct the study. The model, shown in Figure 2-1, relates the information considered in making a change, with the decisions that are made, either explicitly or implicitly, during the change order process. The model accurately reflected the procedural steps observed in the organizations examined, and should serve as a generalized model, applicable to any organization. From this model, specific types of information to be collected were identified. This information included initiator, reason for change, type of work, whether the change was optional or not, the date the change was identified, and amounts and dates associated with the negotiation of the

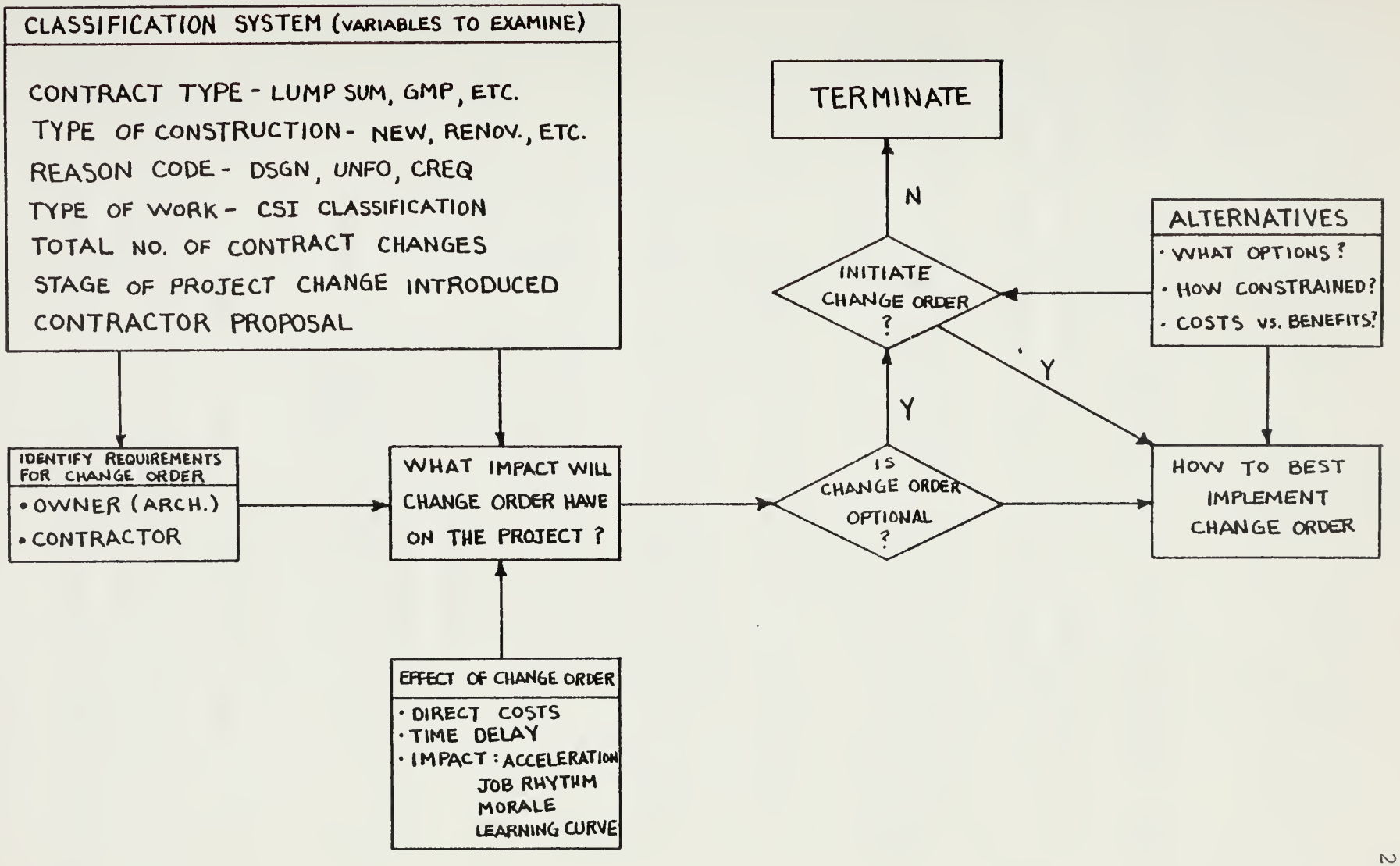

FIGURE 2-1: CHANGE ORDER FLOW DIAGRAM

change. The categories of information, why they were selected and what their significance is, will now be discussed.

INITIATOR: Who identified the need for the change, the owner or contractor?

This data can point to trends in types of changes as to who identifies the need for the change.

REASON CODE: Why did the changes occur? The reason codes are based on those used by the U.S. Navy, consolidating similar categories and including additional categories as suggested by the project managers. The reason codes included are:

1) DSGN - design error or omission
2) UNFO - unforeseen or differing site or work conditions
3) owner initiated:
   a) CREQ - customer requests by user
   b) OPS - operational change in the facility
   c) FUNC - functional change in the facility
4) improvements to the facility and reductions in cost:
   a) MATL - material substitution
   b) VALU - cost savings
   c) IMPR - improvement to the facility
5) contractor initiated:
   a) CC - contractor convenience
   b) CLAIM - claims by contractor
6) other:
   a) OPT - design option by owner specified in original contract
   b) ALLOW - allowance items included in original contract
   c) MISC - various others

The reason codes proved to be a very important piece of information that grouped changes into categories of why they occurred. This data can provide insight into problem areas in the project organization which can lead

to improvements for more efficient operations.

TYPE OF WORK: What type(s) of work did the change involve? The Construction Specifications Institute's categories of work were the basis for this information. The categories included:

1. General Requirements
2. Site Work
3. Concrete
4. Masonry
5. Metals
6. Wood & Plastics
7. Thermal & Moisture Protection
8. Doors & Windows
9. Finishes
10. Specialties
11. Equipment
12. Furnishings
13. Special Construction
14. Conveying Systems
15. Mechanical
16. Electrical

This data pointed out types of work that typically experienced the most change orders.

CHANGE OPTIONAL: Was the decision to go ahead with the change order optional, i.e. was it possible to complete the facility and have it perform its intended purpose without the change in question?

This information was not collected for all the projects, because it turned out to be very subjective depending on who was asked. While this information is important in the change order process to decide whether to go ahead with the change or not, in practice it is not always explicitly considered by the contract administrators. A discussion of the difference between organizations in the change order decision-making process is included in Chapter 4.

DATES & AMOUNTS ASSOCIATED WITH THE PROGRESSION OF CHANGES: There were a number of different dates and dollar amounts recorded when available in the project files. These included the earliest date a change order was identified, the date a request for proposal was submitted to the

contractor, the date the proposal was received and the amount of the proposal, the date notice to proceed was given, the date of negotiations and the final amount agreed to, and the date the change order was formerly accepted in writing.

The dates in project files often appeared to be arbitrary as a result of their being recorded when they reached the typist and not reflecting the specific date decisions were made or key steps in the process taken. There was no detailed analysis performed using the dates as a result of this. If a change was significant because it occurred late in the project process, this usually came out in discussions with the project manager. There was also no attempt made to analyze the negotiating process between the owner and contractor by comparing proposed amounts to final settlements.

General information about the projects was gathered during interviews with the project managers. Major problems that occurred on the project and significant changes were identified by the project manager and factors that made these important were discussed. Working relations between the owner architect and contractor were an important factor on all the projects examined. An assessment of the working relations was made, based on the feelings of the project manager and the degree to which that opinion could be substantiated by the facts of the project.

BIASES IN THE DATA

In gathering the data, there were a number of recognizable biasing factors which should be discussed. These included the following.

1) The information was gathered from the owner's files and through discussions with the owner's project managers. Formally documented information is generally recorded to reflect a good impression. While not deliberate, there is a tendancy for written records to emphasize the perspective of the writer, thus making the situation appear better (or worse in some cases) than it really was. As a result of the source of the information only one perspective is contained in most of the data, namely that of the owner. On the M.I.T. project for the Health Services building, an interview was held with one of the contractor's project managers to include a different perspective.
2) There were several factors that may have led to inconsistencies in categorization of the data.
   a) The framework for collecting the data was refined during the course of research and once the final format was decided, data on previous projects was adapted to fit.
   b) Changes did not always clearly fall into the categories being utilized and for this reason may have

been subjectively placed in different categories. In addition, some changes were classified under two categories in situations where that seemed appropriate.

c) All the projects had outstanding claims and/or change orders that were not included in the data collected.

3) The number of changes or change orders that occur on a project are often arbitrary, because different contract administrators separate the work in different ways. They may include a major change in the building design in one change order, or separate it into a number of specifically identifiable segments of work.

4) There were also some observable differences between the type and nature of information gathered for this study. Some of the information was easy to retrieve from the files, unambiguous and would be readily agreed to by all parties. On the other hand, some of the information was subjective, not directly available in the files and disputed by the parties involved. There were two major categories into which the information appeared to generally fall, "identification" and "assessment." Information that was identification could be objectively determined by an established definition. Assessment information involved a subjective decision process. The types of information

for the categories of data collected in this study are shown in Table 2-1.

5) The level of documentation for different types of information also varied on the project. In some cases the information was accurately recorded in the project files. For some information there was a record in the project file, but portions may reflect arbitrary information. Then there was information that was not recorded in the files, but could be recalled by project managers. Finally, there was information that was neither recorded nor recalled by the project managers.

These fundamental differences between the types of information, and the potential biases present when it is collected, should be kept in mind when the information is used as a basis for project analysis.

CONCLUSION

The objective of this research is to identify the characteristics of significant changes and their resulting impact on the project. In his presentation, "Impact - The Real Effect of Change Orders," C. J. Collins proposes three "phases" of a change order that contribute to its effect on construction. As paraphrased from his paper, they include the following.

CATEGORY OF DATA	IDENTIFICATION	ASSESSMENT	SOMETIMES ARBITRARY
INITIATOR	X		
REASON CODE	X	X	
TYPE OF WORK	X		
CHANGE OPTIONAL?		X	
DATES	X		X
AMOUNTS-TIME & COSTS		X	
WORKING RELATIONS		X	
CONTRACT TYPE	X		
TOTAL NO. CHANGES	X		X
TOTAL VALUE CHANGES	X		

TABLE 2-1: TYPES OF INFORMATION BY CATEGORIES OF DATA

Phase I: Direct Costs - for the actual work to be done
Phase II: Time Extension - to be allowed for the work
Phase III: Impact - four major sub-headings of impact
a) acceleration
b) job rhythm
c) morale
d) learning curve

From this framework it becomes evident that the significance of a change order is measured not only in terms of direct costs and time for the work to be accomplished (added, deleted or modified), but that also the incidental effects of changes need to be considered. In addition, the significance of a change should account for the amount of management effort required by the owner, architect and contractor. This may include redesign, information gathering, and coordination of building components and trades. The combination of documented information gathered from project files and the experience of the project managers as brought to light through interviews, was designed to assess the major factors and determine the impact of significant changes.

CHAPTER 3

HIGHLIGHTS OF THE PROJECTS

INTRODUCTION

This chapter presents a discussion of the major characteristics and significant events of the six projects investigated. A short project description is given for each job that reviews the type of construction, the type of contract, the contract amount, the start and finish dates, and major problems or effective management techniques that stand out on the job. The factors that contributed to significant occurrences in the project development will be discussed to provide some background.

In examining the significant characteristics of changes and their influencing factors there is an implicit assumption made that some standard or norm exists. In construction every project is unique and different, therefore it is dangerous to establish a norm. However, for the purposes of comparison the assumption will be that a "traditional" contract for new construction is the standard. This implies that plans and specifications were completed under a separate design services contract,

prior to the advertisement for construction bids. A further assumption will be made, that a lump sum contract is awarded on the basis of a competitive bid process to the lowest qualified bidder.

In evaluating each project it may appear that only the problems are being discussed. The reason for this is that problems may indicate areas that need improvement. Hopefully, by examining these problem areas and trying to determine the events that led up to them, better methods of managing a project can be suggested. In this way similar problems can be avoided in the future. Extremely effective practices will also be discussed in an effort to encourage continuation of these management techniques.

There is no intention to criticize any individual or organization in discussion of project problems. Construction management is a demanding and complex task and every project is likely to experience difficulties. The author was extremely impressed by the professionalism of the individuals he had the privilege of working with. A great deal was learned from their experience through the discussions of the projects they worked on. Some of the assessments made of project organizations and management techniques may be a result of the author's association with the Navy's Civil Engineer Corps. For this reason, they may reflect the objectives of military construction

and may not be valid for other organizations. With these ideas in mind the six projects will now be discussed.

APPLIED INSTRUCTION BUILDING (AIB)

This project is a concrete block classroom building for the U.S. Navy located in Orlando, Florida. A lump sum contract was awarded on the basis of a competitively bid price of $3,857,000. The contract date was 18 July 1979 with work starting on 2 August 1979. The original estimated completion date was 23 January 1981 with substantial completion occurring on 30 January 1981. Nine days extension were granted on two changes. The contractor was a joint venture firm falling under the federal guidelines for small businesses. The building was designed under a separate contract for design services with a civilian architectural firm and completed prior to bidding for construction.

Relations between the owner and the contractor were good. There were quite a few claims submitted by the contractor for this size of project; however, the owner established a "hard-line" for negotiation and several of the claims were withdrawn because of lack of supporting evidence.

There were no major changes on this job and the

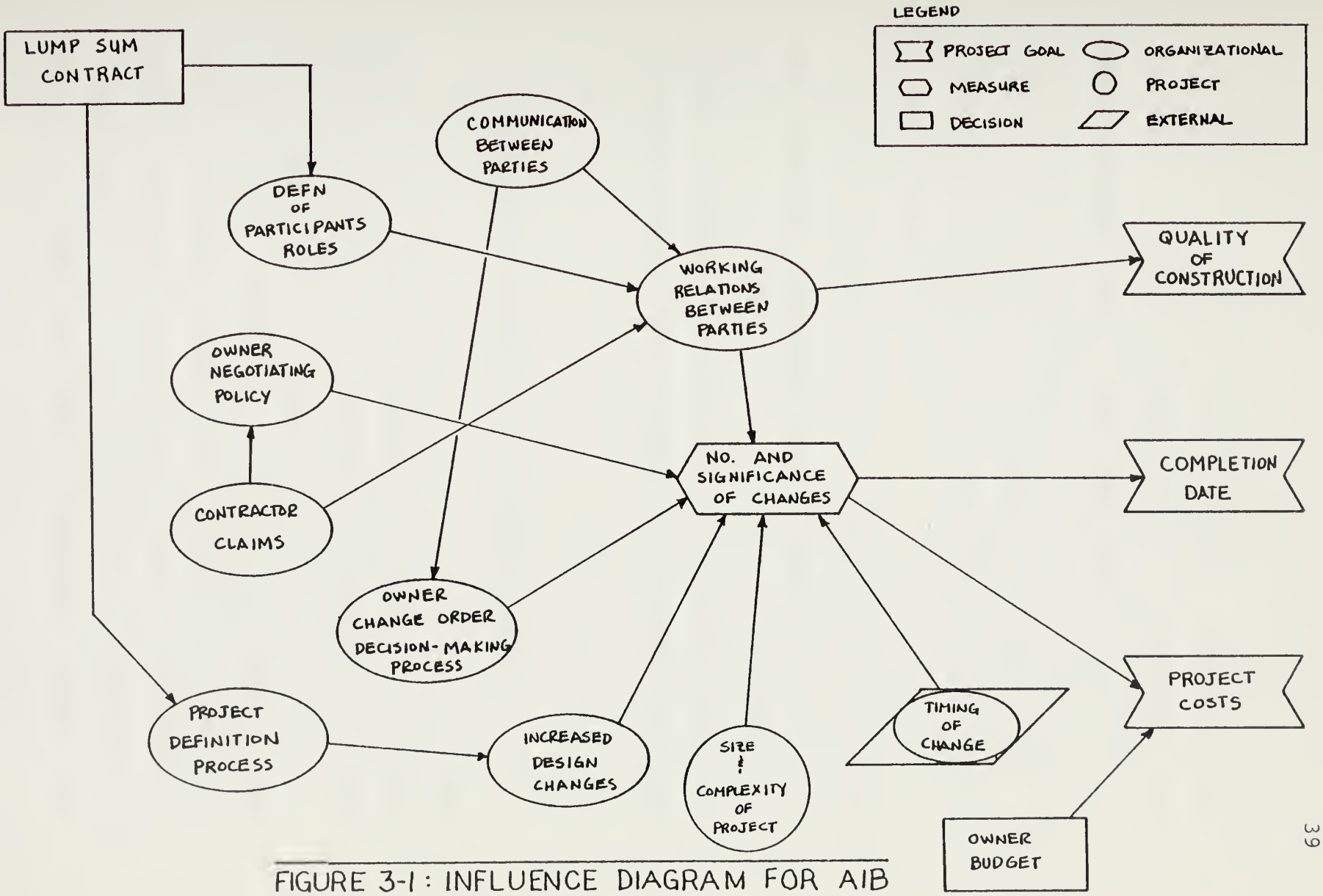

FIGURE 3-1 : INFLUENCE DIAGRAM FOR AIB

total number of changes was the smallest of all the projects examined. The majority of contract modifications occurred as a result of design errors and omissions, but none were significant. Two changes resulted from a change in the manufacturer's specifications on a cooling tower, with no delay in the project. In the case of aluminum service cable being unavailable, a substitution of copper cable was made.

This project was unique in that no major, unforeseen conditions were encountered and no significant changes occurred on the job. The smaller size of the project, standard construction specified and insignificance of unavoidable delays contributed to the smooth progression of work.

ALTERATIONS & RENOVATIONS TO BUILDING E-51 (E-51)

This project, unlike any of the others, was a renovation of an existing building to be used for classroom and office space. The contract was awarded on the basis of a competitively bid lump sum in the amount of $3,664,937.41. Work began on 15 July 1980 and the contract was dated 16 October 1980. Completion was originally scheduled in two phases; to allow for occupation of the classrooms and some administrative spaces for the 1981 fall semester beginning in September. Phase I was

scheduled to be completed on 1 July 1981 which included those areas most needed, classrooms and some office space. The remaining portions were included under Phase II which had a scheduled completion date of 1 November 1981.

A strike by the carpenters, welders and masons beginning in June put the project behind schedule. In order to minimize the impact of the strike and accommodate material delays, the owner's priorities for completion were changed. Areas that had craftsmen and materials available were worked on to keep the project going. A decision was made not to open any areas for occupation until enough was completed to prevent interference between users and workmen. The majority of the building was substantially completed on 20 November 1981. Substantial completion for the third floor, pedestrian bridge adjoining building E-52 and the lecture hall occurred on 5 January 1982.

The owner and the contractor had good working relations. There were a number of small no cost changes performed by the contractor that were not documented on a formal change order agreement. These changes were handled on an informal basis to reduce the administrative burden of formal documentation for both the owner and the contractor. The owner's project manager felt the contractor went out of his way to accommodate the owner's

desires, perhaps to the point of losing money on the job. At completion, there were ten change orders including seventy-five changes.

Renovation work by nature is associated with an increased number of changes, many of which occur as a result of unforeseen conditions. This was true of the renovation to E-51, which had the highest percentage of unforeseen conditions of all the projects examined. There was also a greater number of changes on this project than on the other projects of comparable magnitude. There are several reasons for this. Over time deterioration occurs on existing facilities, requiring additional work and creating conditions that are unexpected. Since previous work is not always done in accordance with the plans and specifications, deficiencies discovered during construction may require correction by the contractor. On this project, code violations of the electrical work above the ceiling in one section, were the cause of a major change. Also, modifications often are not accurately represented on as-built drawings, and this may lead to alterations in the construction. Furthermore, due to changes that occur over time in building systems, old components may not be compatible with new components. Therefore, some assumptions made by the designer are incorrect and require changes in the work.

The construction procedures planned by the contractor also may not be feasible. This could be because of space limitations in the building which require tearing out restricted areas or modifying the construction materials and components to fit. A beam on this project had to be moved to allow for passage of new ductwork. There were also a number of changes on this project associated with the rerouting of mechanical systems to avoid obstructions. Finish work also can present problems because of the difficulty in matching old and new. In addition, tieing in new sections to the existing structural framework can pose problems. Most of the unforeseen conditions leading to these difficulties cannot be detected by inspection and therefore do not become evident until work has begun. For this reason these changes often require rapid resolution to prevent delays in construction.

On this particular project the strike was the single most significant factor in delaying the work. In addition to stopping the carpentry, masonry and welding work during the period of the strike, it caused the priorities for completion to be changed and the sequence of work altered. This disrupted the progression of work and reduced efficiency in output. The project manager and contractor revised their schedules to reduce the impact of the strike and material delays by performing work that could be done

with materials and craftsmen on hand.

There were many changes initiated by customer requests and changes in functional requirements of the facility which were introduced during the construction phase. These sometimes occurred as a result of users seeing what the project was beginning to look like and changing their mind. An inability in being able to visualize the finished product on drawings was a contributing factor to this. Some changes were made to suit the personal preferences of employees. The cost to the owner in allowing these changes for employee satisfaction is the delay in completion of work and increases in construction costs. The owner must assess if the benefits in user satisfaction outweigh the additional cost of construction. User requested changes to offices on the second floor and a classroom on the third floor had major impact on this project.

To define user objectives, the engineering and architectural services at M.I.T., develop a project program. They try to incorporate all the facility requirements as defined by the user representatives. It is difficult in a large and diverse organization such as M.I.T. to include all the desires of the individuals involved. It is incumbent upon the user representative to ensure that all appropriate personnel have the oppor-

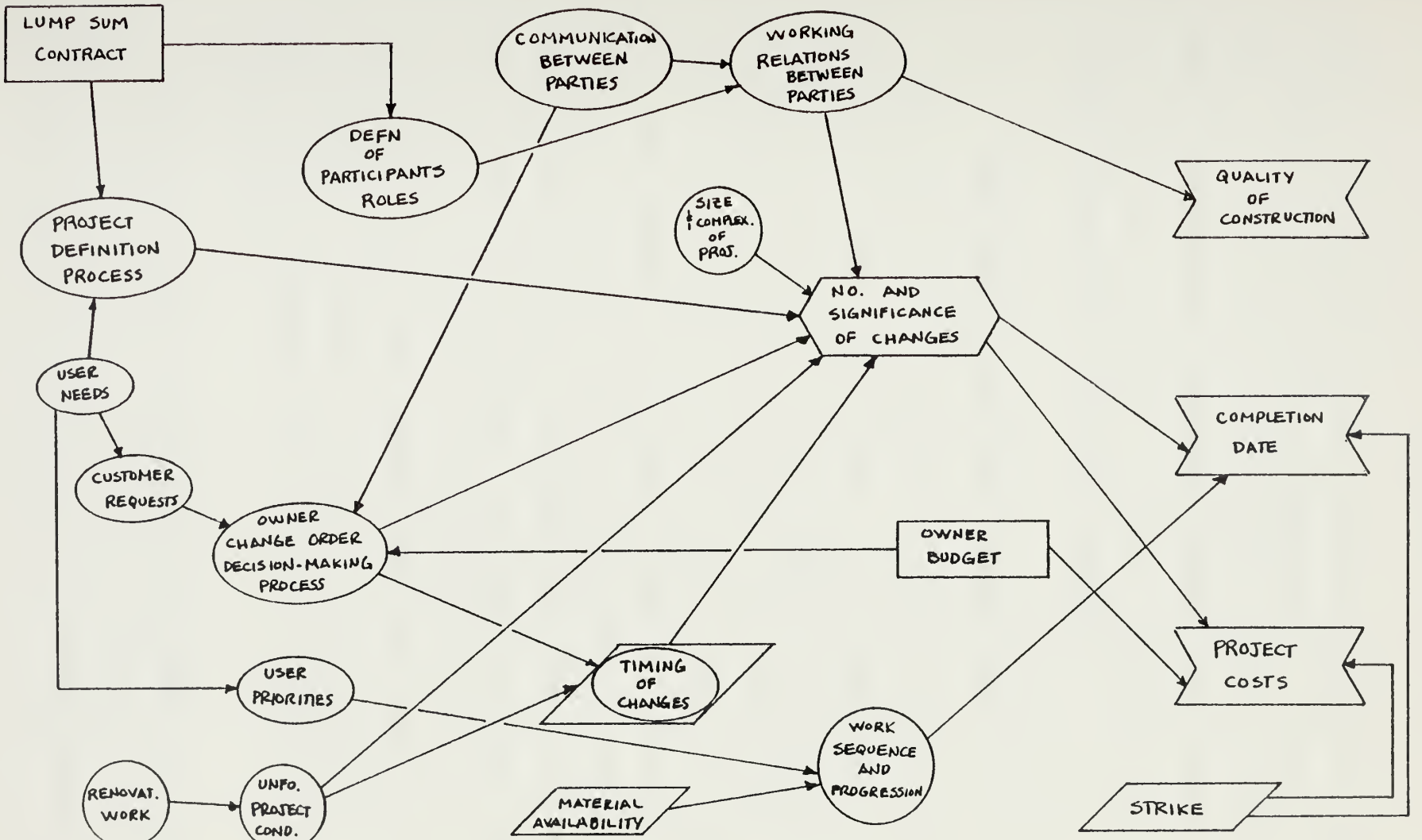

FIGURE 3-2 INFLUENCE DIAGRAM FOR E-51

tunity to provide their input to the project definition and review the final plans for compliance. An established policy of what will be accepted as a legitimate change would encourage users to identify their needs early and reduce the number of changes resulting from customer requests and functional changes.

UNACCOMPANIED ENLISTED QUARTERS (UEQ)

This project is a barracks for the U.S. Navy at the base in New London, Connecticut. It is steel beam and column construction with precast concrete floor panels and concrete block and brick walls. The building was similar to a barracks previously constructed on the same base. The design was performed in-house by the Northern Division of the Naval Facilities Engineering Command, incorporating solutions to problems encountered on the first project into the second. The same contractor that built the first barracks was awarded the contract for the second on the basis of a competitively bid lump sum, in the amount of $7,600,000. Working relations between the owner and the contractor were excellent, the best of any project examined.

The date of the contract was 26 September 1980 with work scheduled to begin immediately. There were two buildings included in the project, the North building

originally scheduled for completion 23 February 1982 and the South building with an expected completion of 3 June 1982. Unforeseen conditions and other changes revised the scheduled completion for both buildings to occur on 7 June 1982.

There were four change orders consisting of fifty-three changes on this project at the time it was examined.

The greatest impact on this project resulted from unforeseen subsurface conditions. More unsuitable rock was discovered upon excavation than was expected. This caused the single most significant change in terms of time delay and increased costs.

There were several changes related to site utility work resulting from design errors. These included elevations of the sanitary sewer and storm drain systems (identified by the contractor) and the requirement for a new telephone pole and duct system (identified by the owner). A more thorough investigation of existing utilities and more detailed planning of service requirements for the new facility, could have eliminated the need for these changes.

Unlike the other projects observed, many of the changes on this project were no cost changes. This was a result of two factors. First, working relations were

so good between the owner and contractor that small changes were accomplished at no additional cost. Secondly, the project manager carefully documented each contract modification with a change order. Many of these type of changes were documented on field orders or authorized verbally on other projects. Although there was a high percentage of design errors and omissions on this project, only nine out of twenty-eight were associated with increased costs. There were fifty-three changes on this project at the time it was reviewed, but only seventeen resulted in modification to the contract price.

The working relations between the owner and the contractor were superb. They were further enhanced by previous experience with the same contractor on another barracks project that was just being completed. This reduced the effort required by the contractor in mobilization and start-up. In addition, it provided continuity of communications and established roles.

This was the only project that had a significant number of suggestions by the contractor to provide an improved facility or more efficient construction methods at no additional cost. On several occasions the contractor suggested better materials or methods of construction that provided benefits to both parties. These suggestions resulted in an unusually high percentage of con-

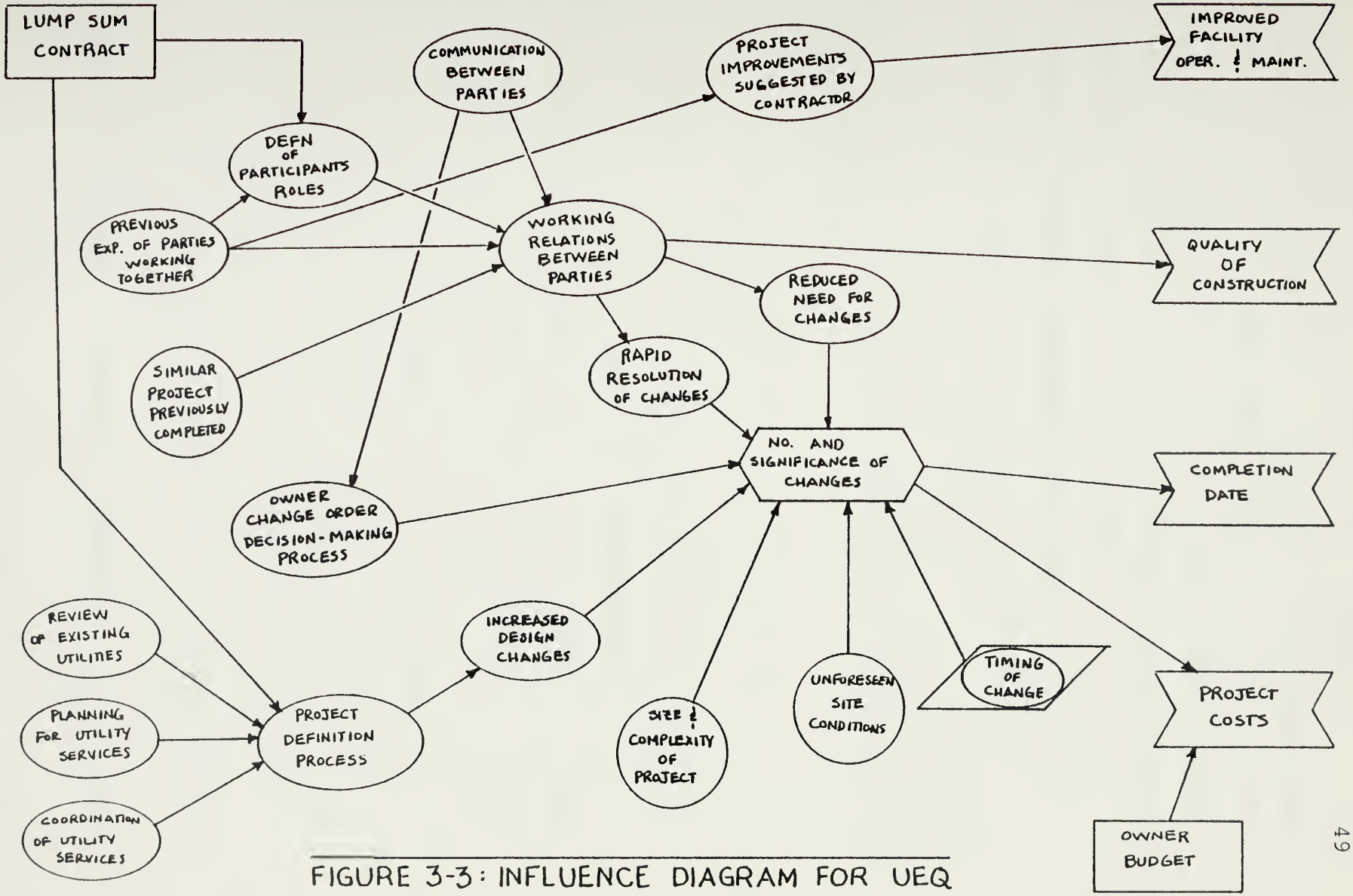

FIGURE 3-3: INFLUENCE DIAGRAM FOR UEQ

tractor initiated changes. The cooperation between the owner and the contractor also led to early identification of the need for changes and timely resolution of change orders. Potential problems were identified and solutions developed to prevent unnecessary delays in the work. In two cases alternate materials were substituted for unavailable material to keep the job going.

As on the other projects observed, a large percentage of the changes fell into the categories of electrical and mechanical work.

500 MEMORIAL DRIVE (NEXT HOUSE)

This project is a brick masonry dormitory building for M.I.T. located in Cambridge, Massachusetts. The contract was for design-build services between the owner and a joint venture made up of an architectural and construction firm. There was a requirement to finish the building prior to the beginning of the fall semester, to provide housing for incoming students. Otherwise the university would have had to make arrangements for alternate accommodations which would have been very costly.

The owner had completed New House, another dormitory of similar construction on an adjacent site about five years previously. A design-build contract with the same

architectural and contracting firms had also been utilized on the New House project. This previous experience provided access to more detailed information on site conditions. In addition, solutions to problems excountered on the first dormitory and improvements in the facility were incorporated into the design for Next House. Although different field personnel were employed by the contractor and a new project manager was assigned by the owner, key decision makers for both the architect and owner were the same. This provided a transfer of experience from the New House project to Next House. During the construction of Next House the owner's project manager changed, this turnover in personnel would usually disrupt the continuity of communications and working relationships between the owner and contractor. However, there was no apparent impact of this on the project.

During the contracting process the owner signed an initial purchase order for design services with the architect on 22 August 1979. A purchase order for consulting services was signed on 11 September 1979 with the contractor. On 19 June 1980 the design-build agreement was signed with the joint venture for a guaranteed maximum price of $8,597,300. It called for completion on 15 August 1981.

During the finish phase of construction the carpenters and masons went on strike for a six week period. This delayed completion of the work and created the need to accelerate the project, causing the owner to incur additional costs for overtime. Substantial completion occurred on 1 September 1981.

There were forty-seven changes on this project, included in eight change orders. The strike encountered during the finish phase was the major cause of the project being delayed. Up until the time of the strike, progress indicated that construction would be completed on schedule. As a result of the need to provide housing to incoming students, the project was accelerated after the strike was settled; this resulted in increased costs for overtime pay and lower quality of workmanship, because of the rush to finish. The strike and subsequent acceleration also disrupted the smooth progression of work which resulted in decreased efficiency.

Some of the characteristics of changes on this project differed from those found on a traditional design-then construct contract. The primary reason for this was that the roles of the owner, architect and contractor changed under the design-build agreement. With traditional contracts, M.I.T. had relied upon the architect to take a general description of the owner's objectives

(described in the project program) and develop a detailed definition of the project requirements in working drawings and specifications. The program development phase allowed the owner to refine original objectives as required, with no effect on construction. The nature of the design-build contract differs in that it is a much more interactive process of project definition between the owner and joint venture. The decision making is more contrained by the actual progression of work and the impact changes may have.

On this project it was observed that many of the changes were the result of customer requests and contractor claims. Many of the customer requests were items the owner recognized as omissions in the original project scope, that were subsequently added. The high percentage of contractor claims that occurred on this project resulted from requests by the owner which the contractor felt were not included in the original contract, but the owner disagreed. This characteristic was a result of the process by which the owner and joint venture went through to clarify and refine the initial project definition. The preparation of a more detailed and comprehensive project program by the owner may have eliminated some of these changes.

Traditionally on much of M.I.T.'s work there was a

reliance on the architect to identify the need for changes, review alternatives and negotiate a fair price with the contractor. Due to the role of the architect in traditional contracts this fitted in well with the structure of M.I.T.'s project management organization. In the case of a design-build contract the owner is required to take a much more active role in the development of project definition and managing of change orders. The role of the owner becomes much more than that of an approval agency and requires the acceptance of greater responsibility in review of plans and inspection of work. The architect is no longer an agent for the owner in negotiations with the contractor, but now the owner must make an assessment of the validity of the contractor's proposals.

This new role requires an efficient approval process which recognizes the need for timely resolution of changes and establishes open communications to clearly define user requirements. Otherwise, processing of change orders will become bogged down in bureaucratic procedure and delay the progression of work. To prevent this, authority must be delegated to the proper working level for approval of change orders. Within the M.I.T. organization authority has been delegated in a manner to accomplish this. The difficulty arises in processing customer requests, because communication of user needs in a large

organization such as M.I.T. is difficult. The project manager must determine whether the user should be involved in a decision about a change order. In the case of a dormitory, the M.I.T. housing office is the user. They are not only responsible for the operation of the dormitory, but for much of the maintenance. For this reason their input needs to be included in many of the change order decisions.

Under the traditional contracting procedures, the approval process can act on a set of contract drawings with few changes. The design-build approach, however, consists of a string of decisions throughout the project. Therefore, a large institution like M.I.T. could benefit from standardized objectives for its facilities, to allow routine changes to be approved as a matter of procedure. In addition, the using department should clearly state its objectives and any specific parameters in a proposal statement to be incorporated into the project program. A user delegate could also be appointed to attend project progress meetings and represent the using department.

On the Next House project several alterations occurred after the appointment of a new housemaster. To accommodate his desires, several changes were approved for modifications to his living quarters. These changes resulted from differences in personal tastes of the new

occupants and were introduced at a late stage during construction. If the design of the housemaster's suite had not accounted for the preferences of the occupants, but had been designed for general use, there would have been fewer disruptions in the work and a lower resulting cost.

The use of design-build services did result in far fewer design errors and omissions. This can be attributed to the relationship between the architect and contractor under this type of contract. Since the joint venture is responsible internally for communication of project requirements, design errors and omission were handled in-house, unless owner action was the cause for the change.

On this project M.I.T. initiated three times as many changes as the contractor. This was unusually high, as compared to other projects examined, and was mainly the result of customer requests to clarify objectives, add omitted items and modify the facility to suit user preferences. This is to be expected on a design-build contract as previously discussed.

As on the other projects reviewed, a high percentage of changes fell into the categories of electrical and mechanical work. The coordination of utilities and HVAC or equipment installation required changes on every

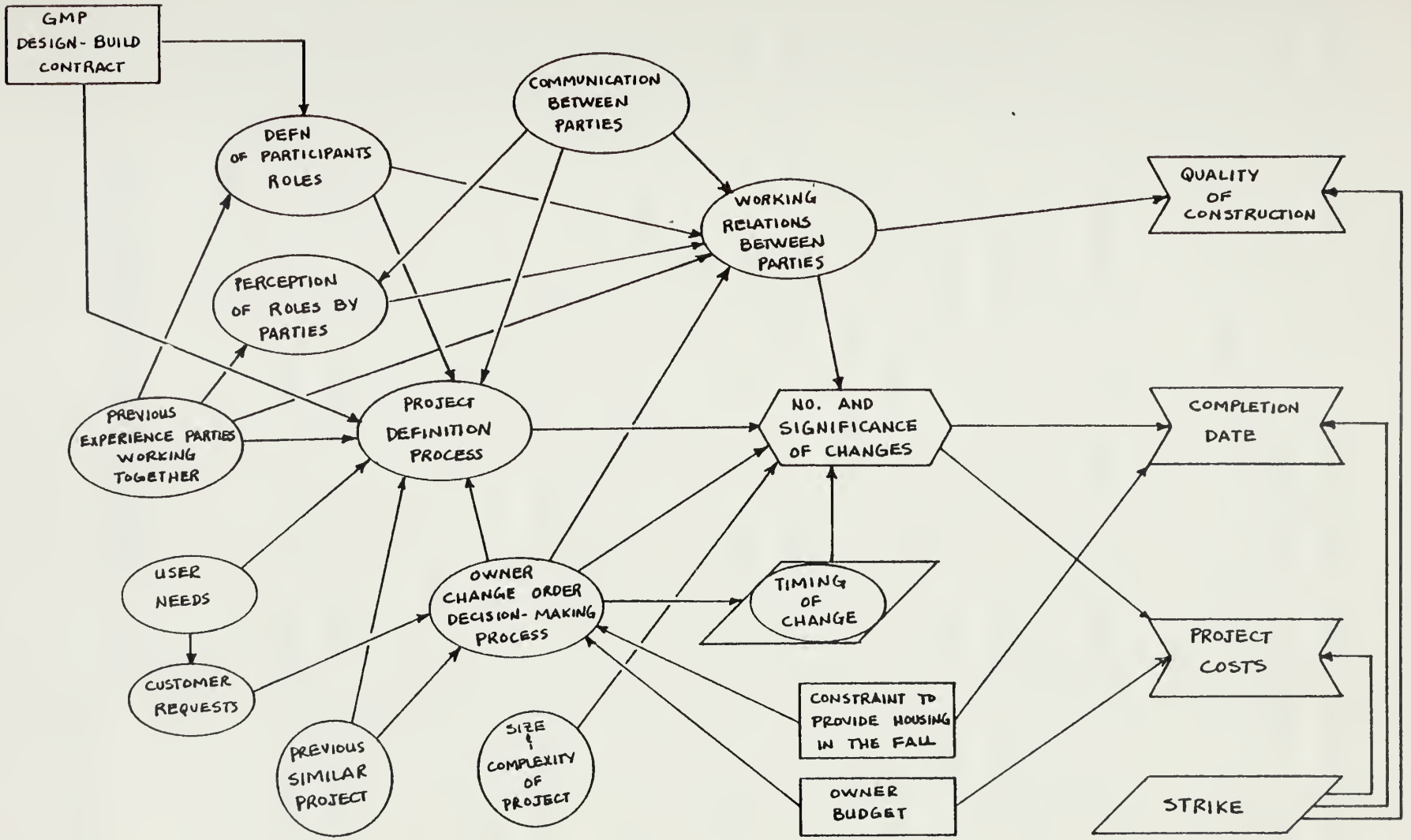

FIGURE 3-4 : INFLUENCE DIAGRAM FOR NEXT HOUSE

project examined. This is due to the level of detail and complexity involved in the coordination of these systems and the impact that modifications to the facility had on this work.

Since the roles of the owner, architect and contractor are different under design-build contracts than traditional agreements, the working relations are also altered. The success of a project is often a direct result of the level of cooperation between these three parties. This is a function of how well each party understands and fulfills their responsibilities under the terms of the contract. When the perception of all the parties is in agreement over what the roles and responsibilities of each of the members is, there is a high level of cooperation. Under the guaranteed maximum price contract there is much greater potential for disagreement between the parties, because of the lack of project definition initially. For this reason each party makes more assumptions about the project, which may or may not be correct. Taking into account the increased disagreement inherent in projects such as this one, working relations were considered good.

NAVY REGIONAL MEDICAL CENTER (NRMC)

This project was for construction of a new hospital

to replace an outdated medical facility at the Naval Training Center in Orlando, Florida. It is a steel frame structure with precast brick masonry panels. The contract was a competitively bid lump sum agreement, in the amount of $16,770,000. The date of the contract was 9 June 1977 with the work to start on 24 June 1977. The initial estimated completion date was 11 December 1979 and was extended to 16 December 1980 after the addition of an energy monitoring and control system (EMCS) to the contract. The beneficial occupancy date (BOD) was established as 12 December 1980, but the construction completion date (CCD) did not occur until 20 August 1981.

Working relations between the owner and the contractor were poor. The prime contractor did not exercise the proper control and coordination over the sequencing and interfacing of work. This led to confusion and disorganization on the project which resulted in low productivity and a great deal of rework. Contributing to the prime contractor's mismanagement of the project was the instability of his on-site supervisory personnel. Many changes in project managers and superintendents were made during the length of the project. This changeover in personnel disrupted the continuity of communications and the familiarity of the project managers with job related matters.

At the time of this research there were twenty-six change orders that included one hundred and eight changes on this project. Five changes on the project had a major impact on the work. Two of these were design problems in the electrical system. One was an omission that provided for an isolated power system and the other was an error specifying revisions to switchboards and transformers. The most significant change to the contract was the introduction of the EMCS by the owner. The contractor also submitted a claim for an unavoidable delay in the delivery of structural steel. There was also a change proposed as a cost savings concerning the precast brick panels.

The design errors in the electrical work were identified early during the construction phase. This allowed sufficient time for materials to be ordered so that no delays were experienced in construction.

The addition of the EMCS was the largest change introduced on this project or any of the projects reviewed. There were three individual changes associated with this addition. The first provided for the installation of conduit to service the system. It was submitted while the system was under design, to prevent stoppage of the construction work. The second change specified the system itself and the third change provided for a maintenance service contract on the system. The overall

change resulted in a 279 calendar day extension to the completion date and over $2,000,000 in increased costs.

The EMCS change was introduced during the construction phase and wasn't finalized until late in the project. It was initiated by an increased awareness for the need for energy conservation. Federal contracting regulations preventing incrementation of project components and subsequent interruptions that would have impacted the hospital operations, precluded adding the system later. The project was already behind schedule when this change was submitted and due to the other problems associated with the work, it is difficult to identify how much impact this change had on delaying completion. Major problems were experienced in the development of computer software and the system never satisfactorily performed in accordance with the specifications. Alternate arrangements were made under which the facility's energy systems are analyzed by a management firm and reports submitted to the user for improved operations. Since most of the delay on this change was in software development the impact on construction should have been minimal.

The Navy has traditionally had problems with EMCS systems and perhaps is pushing the state of the art, by specifying requirements beyond the present capabilities of the technology. A review of the specifications along

with research into the technology's capabilities should improve performance on future projects.

The delay in the delivery of structural steel was a result of extreme winter weather in the Northeast where the steel fabricator was located. Transportation was unavailable for several months and delayed the progress of construction. A 90 day extension was allowed for this unforeseen condition. Other delays in delivery of steel decking and brick also impacted the construction work. These delays were caused by events external to the project and beyond the control of the owner and contractor.

As a result of a change in the high strength mortar specified for the precast brick panels, the contractor suggested a change allowing laid in place brick in place of precast panels. This recommendation was associated with a cost savings, so the owner asked the contractor to present his design and proposal. The design was rejected by the owner and went back and forth several times before an agreement was reached. At this time the contractor submitted a claim for increased costs of construction and overhead. This was unacceptable to the owner, so the original method of construction was again specified. The contractor felt he had been misled and submitted a claim for increased costs. This procedure took several months and required a lot of management effort

by both the owner and contractor. As a result of the disagreement it further strained the working relations between the parties.

The largest single source of changes on this project was design errors and omissions. Most were small changes, usually omissions from the original design or minor revisions required. Many were in the area of electrical and mechanical work. On a hospital project this should be expected because of the complexity of the systems involved and the difficulty of specifying all the details. Approximately one-half of the changes resulted from design errors and omissions and about three-quarters involved electrical and mechanical work.

On many projects unforeseen site conditions are an area that create significant changes because they are unexpected and cannot be planned for. Although a number of changes on this project resulted from unforeseen conditions, none of them had a mjaor impact on the job.

Although there were several significant changes to the project, this was not the major factor in the late completion of the job. Sufficient time was allowed in the negotiation of change orders to complete the additional work. Poor management by the contractor was the single greatest factor in delaying the completion date.

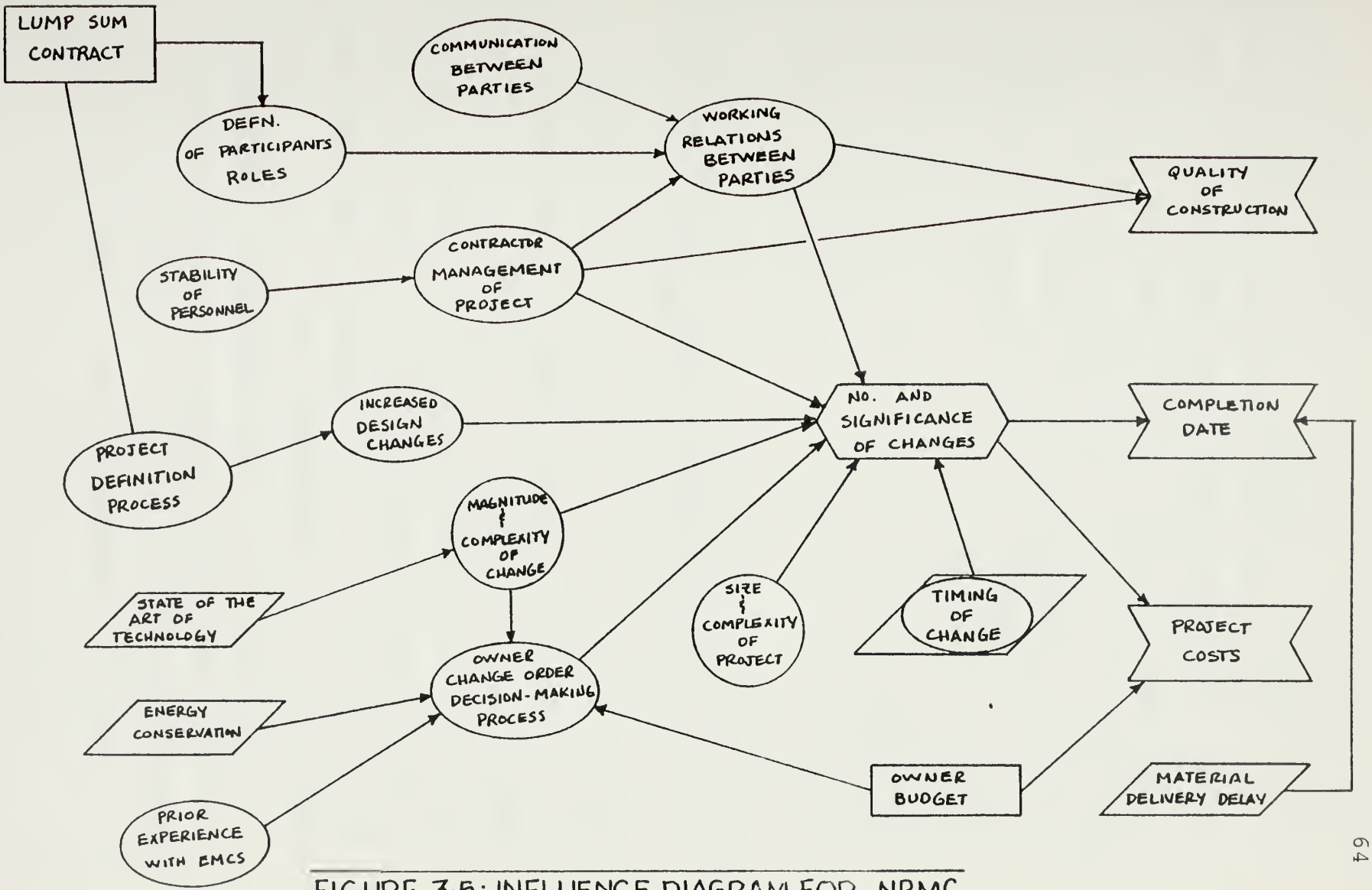

FIGURE 3-5: INFLUENCE DIAGRAM FOR NRMC

Lack of coordination and control over the subcontractors and inadequate project manning resulted in conflicts among the trades and rework. This decreased the motivation of craftsmen and resulted in the job taking longer than it should have and caused a reduction in the quality of work. At the end of the project several contractor claims were outstanding, these were allegations by the contractor of delays caused by modifications initiated by the owner. All these factors point to poor working relations and a breakdown in communications between the parties involved.

COLLEGE OF HEALTH SCIENCES, TECHNOLOGY & MANAGEMENT (HSTM) AND HEALTH SERVICES BUILDING (HS)

This project consisted of two separate, but related facilities that were constructed under a single contract. One was a college building for health sciences including offices, research facilities and classrooms (HSTM); the other was a health services building to provide health care facilities for members of the M.I.T. community (HS). The two facilities were constructed on the M.I.T. campus in Cambridge, Massachusetts and are adjoining brick buildings connected by a central atrium. For the purposes of construction this was a single project, separate accounts were kept on costs in accordance with the

requirements of the owner. Due to the difficulty of discerning what changes went with what facility, the change orders for the complete project were reviewed.

A contract for cost plus a fee, with a guaranteed maximum price was utilized for construction. The original contract price based on 60% drawings was $24,835,000, with $15,742,000 for HSTM and $9,093,000 for HS. A purchase order was signed to initiate the project, work began on 22 August 1979 and a GMP contract dated 20 June 1980 was signed after the contractor submitted a price. The estimated completion date was originally 31 August 1981, but substantial completion did not occur until 1 February 1982. There were eleven allowances in the contract to control expenditures.

During the course of this project there were four major changes that had a significant impact on the work. Due to unforeseen conditions, modifications to the site utilities resulted in a major change. In addition, the owner initiated three major alterations to the building. First, a sixth floor was added and the contractor was asked to submit an estimate for the work based on a "typical" floor, before knowing the details. Second, in order to allow for future expansion, the compactor building design was changed. Third, a large number of changes were introduced to move partitions, modify electrical and

mechanical work and alter the plans to meet the specifications of the users. These four major changes included many specific changes to the contract.

There were more changes to this contract than on any other project reviewed. This was mainly due to the three major modifications introduced by the owner and the large volume of customer requests. Unlike the other jobs examined, most of the contract modifications were documented on a separate change order. At the time of review there were over 300 change orders, completed or under review. A number of change orders on this project involved adjustments to allowance items. These served more of an accounting purpose and did not necessarily reflect changes to the original work or the true magnitude of the effort involved.

On this project the roles of the owner, architect and contractor were very similar to those found in a traditional design-then construct contract. The owner developed a project program that incorporated the needs of many individual users. From the program objectives, the architect prepared plans and specifications to define the project in terms of quantity and quality. The contractor constructed the facility as set forth in the contract documents.

Effective communications was a crucial requirement for the success of this project. The complexity of building systems, the size and diversity of the organizations involved and the time factor, compressed by the fast tracked schedule, made the uninterrupted flow of information a necessity. The location of the architect in New York created a physical separation that further complicated communications. In addition, communications were severely hindered by personality conflicts between key personnel in the architectural and construction firms. This resulted in poor working relations, which greatly hampered smooth progress on the job.

In the construction of a fast tracked project, the key element is that project definition (proper preparation of plans and specifications) precede construction, allowing sufficient time for the contractor to procure materials, plan the work and mobilize the work force. This requires that the project be separated into stages which can be constructed independently of one another. On a project such as a medical facility which consists of complex and interdependent systems, key decisions including equipment selection and mechanical/electrical services need to be made early. Once specified these critical components cannot be changed without severe impact on the construction.

The decision to modify the foundation of the compactor building, to allow for future expansion, was introduced at a stage in construction that required some rework and delayed progress. Also, throughout construction of the project, the process of defining the major changes to the sixth floor and the compactor building, lagged behind the time frame required to allow for proper project planning. This was one of the major reasons there was such a large volume of customer requests. Instead of adequate specifications being included in the contract documents, change orders had to be introduced. In addition, a large number of modifications to partitions, electrical and mechanical services and details of layout and finish work was submitted late in the construction phase and continued right up until the end of the project. In order to reduce the number of customer requested change orders and their impact, an assessment by the owner should be made as to the need for the change. A decision on whether the change is a requirement for the proper operation of the facility or is just a matter of preference should be made. If it is merely preference, the owner must determine if the delay in time and increased costs, outweigh the benefits associated with the change. On this project the high percentage of late changes greatly reduced the productivity of workers and resulted in rework on a number of occasions. As a result

of inadequate information being supplied to the contractor or insufficient time to plan the work, many of these changes were accomplished on a time and material basis.

Two key factors contributed to the problems resulting from so many customer requests. First, specific user requirements were not identified early enough in the project development stage. This meant there was not sufficient time for proper design, planning of work and completion of construction. As a result of this, preparation and preliminary work on construction began prior to receiving complete specifications. For this reason there were disputes on a number of changes between the architect and contractor over the scope and costs of the work involved.

In an organization as large and diverse as M.I.T., internal communications becomes a major problem. Under a fast track schedule of construction the bureaucratic channels of communication are insufficient to meet the needs of rapid decisions and problem resolution. A user representative is a key figure in the successful development of a satisfactory facility, incorporating the needs of a wide range of individuals into the project scope. A time schedule of specific decisions and when they must be made should be established. If after the deadline a change is proposed, it should be determined whether the

change is required to complete the facility or if it is optional. The owner must take into account the impact on the completion date and construction costs if the schedule is delayed, when deciding on whether to go ahead with the change or not. To ensure user requirements are being met, a review process of the plans and specifications should be coordinated by the user representative, to include key individuals who understand the project requirements.

On this particular project many of the researchers and employees for the college of health sciences had not been hired during the project development stage. Because of the competitiveness of attracting well known researchers to an institution, M.I.T. was willing to make changes to suit the personal tastes of the individuals hired. In the case of the health services building, however, most of the employees were already on hand, and still a large volume of customer requests were authorized.

The need for effective communications between the owner, architect and contractor increases under the fast track schedule. The reduced time available makes the efficient flow of information and rapid resolution of problems a necessity. Areas of responsibility between the architect and the contractor, also become less definable as a result of the time factor. The roles of these two parties is clear, but their application in

specific instances, involving overlapping areas and interdependent decisions, is more difficult to determine. This may become an issue in decisions affecting construction methods, where the design phase period and construction planning or material procurement period overlap, thereby creating an area of potential conflict.

The owner is the ultimate authority in assuring that each party fulfills their obligations and in identifying bottlenecks in the system, because he is the controlling party in the contract. In the case of M.I.T.'s projects, this responsibility is usually delegated to the architect who is charged with reviewing change orders, screening alternatives and negotiating a fair price with the contractor. In traditional contracts the architect is in a position to act as a neutral third party; because the design phase is complete and the architect is responsible only for design errors and omissions, which are generally easily distinguished. In fast track projects, however, the architect is not able to function as a neutral party. Since project definition is still under way after construction begins, the issue of the responsible party, in the event of a change, is more controversial. The architect now has a vested interest in the matter and is less likely to be objective.

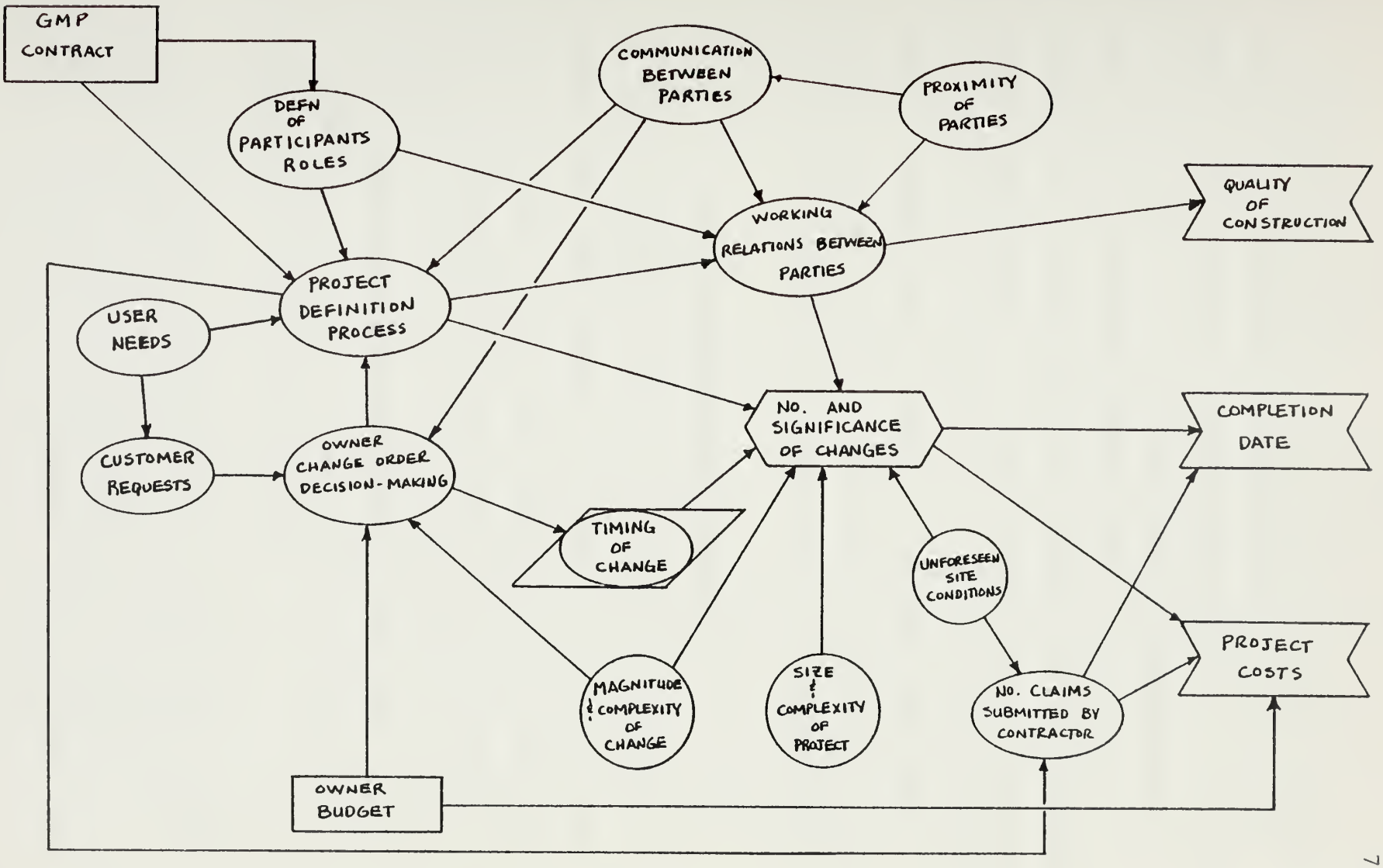

FIGURE 3-6: INFLUENCE DIAGRAM FOR HSTM

A possible solution to the need of improved communications and definition of responsibility is to utilize design-build services if a fast track schedule is desired. This would create more informal lines of communication and closer ties between the architect and contractor. A common goal is established that promotes close cooperation between these parties. It also eliminates the concern by the owner over clear definition of project specifications between the designer and builder. However, this also places a greater burden on the owner to take a more active role in the management and negotiation of change orders.

MAJOR PROJECT CHARACTERISTICS

After reviewing these six projects it should be apparent that each job had a character of its own; however, some major factors were relevant to all the projects. These factors can be classified in three major categories. These are organizational characteristics, project characteristics and external conditions. Each of these categories will be discussed to develop an understanding for what they include.

Organizational characteristics include the working relations between the parties, the project definition process, and the owner change order decision-making process. The selection of the type of contract and the

establishment of the project budget by the owner, are important decisions which need to be made early in the project. The type of contract utilized is the first factor to examine in the analysis of any project. In theory, the contract assigns the roles and responsibilities to the project participants and careful consideration should be given to its selection. Since the owner is the key figure in selecting the type of contract to be used, it is incumbent upon the owner or his agent to consider the project objectives, organizational characteristics and environmental conditions in the selection of the most appropriate type of contract. The contract is the foundation upon which the project organization is formed. The type of contract selected will greatly influence the other project factors.

The working relations between the project participants indicate the effectiveness of communications and level of cooperation on the job and are influenced by a number of different factors. The roles assigned to the participants in a project are a major factor in how the parties will interact. Although the authority and responsibilities assigned are formally defined in the contract, in reality they are not always consistent with the roles actually performed on the job. There is a variation between what each member perceives his role to be and what

the other members perceive that party's role to be. This leads to expectations by all the participants, that the other participants may or may not be aware of, and if they are aware of them, they may or may not be willing to fulfill them. The greater the disparity between what the project participants expect of each other and what actually occurs, the longer it will take to resolve disputes and the greater impact changes are likely to have on the project. Other key factors which affected the working relations on the projects observed, included the effectiveness of communications between the parties, previous experience of the parties working together and the proximity of the parties while the project was in progress.

The project definition process is another organizational factor influencing the change order requirements on a project. The definition process for a project involves the communication of the owner's concept for the facility, through the architect who develops detailed plans and specifications, to the contractor who constructs the building. The communications flow for the project process, including conceptual design changes, is shown in Figure 3-7. The process while conceptually the same for all projects, is much more interactive for fast tracked projects. The relationship between each of four

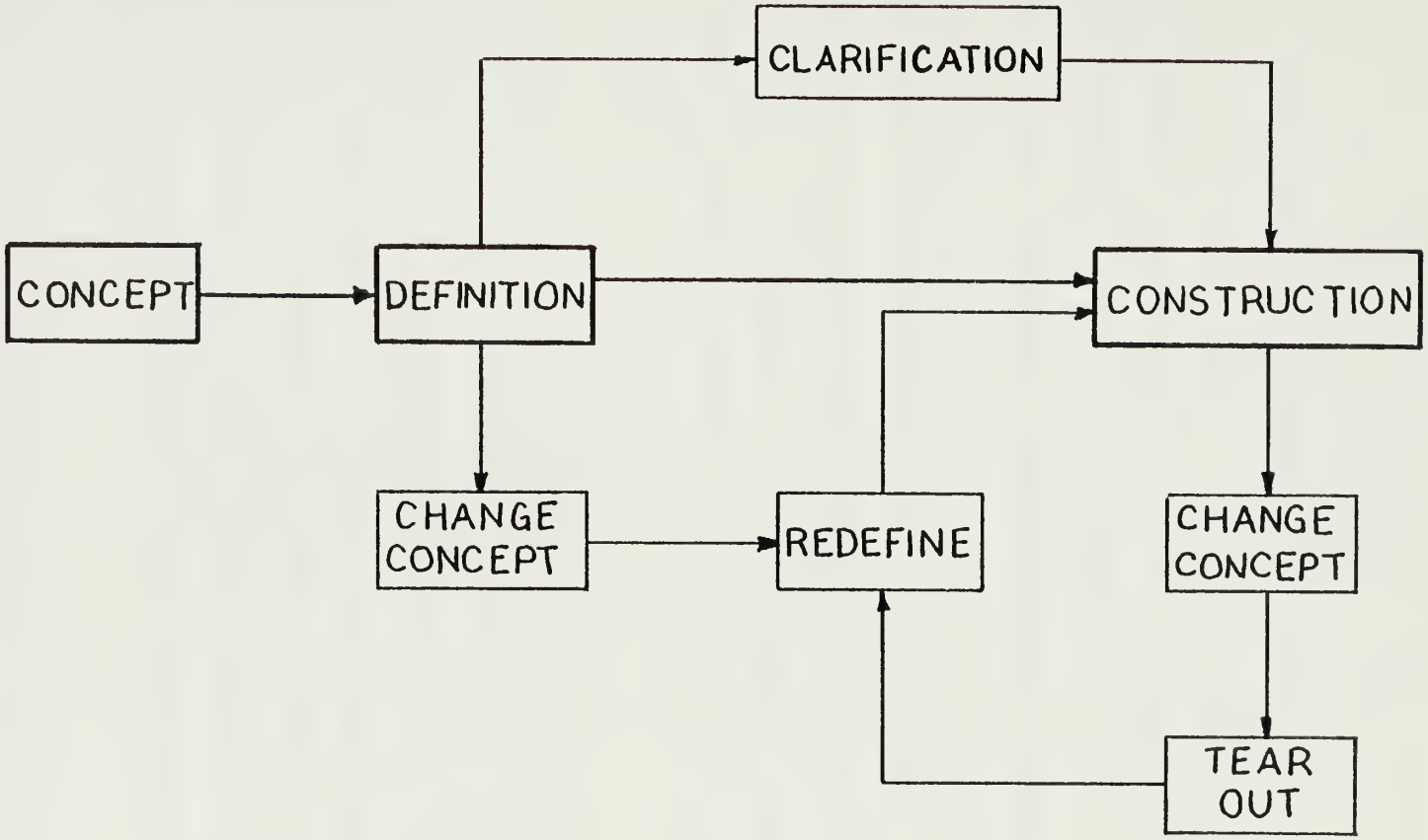

FIGURE 3-7: COMMUNICATIONS FLOW OF PROJECT PROCESS

project phases and the flow of communications is depicted in Figure 3-8. Each of the different symbols represents one of the major project participants, beginning with the owner in the middle and proceeding out, through the architect, to the contractor. The solid lines eminating from the center, represent the flow of communications, while the concentric circles represent the owner's project program, the architect's design process and the contractor's construction schedule. There is an increased need for effective communications to ensure proper coordination between these three aspects of the project. Changes to the work generally create a greater impact on fast tracked projects because of the interrelatedness of these factors.

The last major organizational factor observed on these six projects was the owner's change order decision-making process. The time required to make a decision and the criteria upon which the decision was based were a result of the organizational structure, organizational goals and objectives, the type of facility being constructed and the effectiveness of the communications between the parties.

An integral part of all the organizational characteristics is communications between the parties. The lifeblood of any organization is effective communications.

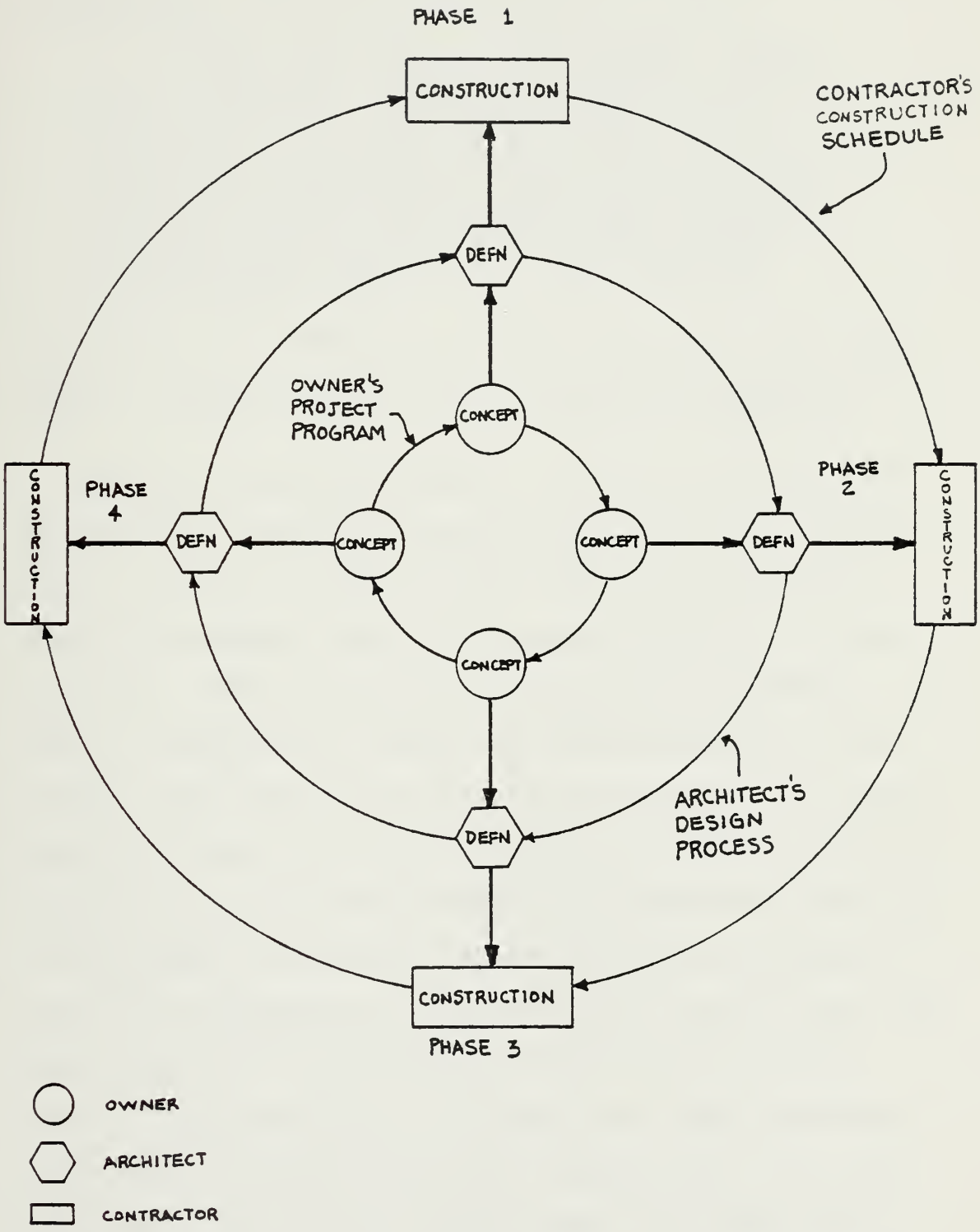

FIGURE 3-8: RELATIONSHIP BETWEEN PROJECT PHASE AND COMMUNICATIONS IN FAST TRACKED PROJECTS

In the CSI Manual of Practice, Project Manual: Procedures & Techniques, the following statement is made.

> "Almost all change order problems involve communications; or the lack of communications. It is imperative that the contractor be informed of the procedures that are expected to be followed, and what information will be required to substantiate claims for extra costs. Good communications and tight controls can minimize change order problems and eliminate bad feelings, particularly with regard to price negotiations."

When reviewing organizational characteristics the importance of communications should always be remembered.

Project characteristics of a job can also greatly influence the number of change orders and their significance. The size of the project generally affects the number of changes, with more changes occurring on larger projects. The type of facility may lead to specific types of changes as a result of the components involved and the users that will occupy the building. For example, hospitals tend to have more changes in equipment, because there is so much to be installed; and hospitals also have a high number of customer requested changes, because of the rapid development in technology and the fact that the same users will be occupying the facility on a daily basis. The complexity of the work will often influence the number of changes and their significance. The more components on a project and the more complicated their relationships, the more changes generally occur and the

greater their impact on the project will be.

Unforeseen site conditions are a typical source of changes that adversely affect the work. Since they are unexpected and because they are not usually discovered until the work is progressing, they are more often significant than most other types of changes. Additional site exploration can limit this impact, but the cost associated with additional investigation makes it extremely expensive. Site utilities, their location and condition, also can be a major source of changes on a project. Improved updating and filing of as-built drawings, along with carefully prepared designs for site utilities could greatly improve this situation.

Other project characteristics that influenced the number and significance of changes on the projects observed included the magnitude and complexity of the change, the type of construction (whether it was new construction or renovation work), and previous similar projects on which the owner and contractor may have worked together, allowing them to incorporate improvements into the project as a result of their prior experience.

Unforeseen external conditions are the third major category of influencing factors. These factors for the most part are beyond the project participants' control.

They include extreme weather conditions, material non-availability and strikes. Insurance against the unexpected and agreements with labor organizations and material suppliers can reduce the impact of some of these factors, but they are factors over which the project participants exercise the least amount of control.

GENERAL INFLUENCE DIAGRAM

The major factors influencing the number and significance of changes, as observed in this research, are summarized below and form the basis for the general influence diagram shown in Figure 3-9.

MAJOR FACTORS INFLUENCING THE NUMBER AND SIGNIFICANCE OF CHANGES

ORGANIZATIONAL CHARACTERISTICS:

* 1) Working relations between parties
    a) definition of roles of parties (difference in assigned roles and perceived roles)
    b) communications between parties
    c) previous experience of parties working together
    d) proximity of parties
  2) Project definition process
    a) communications between parties
    b) prior planning
    c) site investigation
    d) previous experience of parties working together
    e) previous similar projects

3) Owner change order decision-making process
   a) organizational structure
   b) organizational goals and objectives
   c) type of facility
   d) communications between parties

DECISIONS:

1) Type of contract
2) Owner's project budget

PROJECT CHARACTERISTICS:

1) Size and complexity of project
   a) type of facility
2) Unforeseen site conditions
* 3) Magnitude and complexity of change
   a) type of facility
4) Type of construction - new construction, renovation, etc.
* 5) Previous similar project between owner and contractor

EXTERNAL CONDITIONS:

1) Unforeseen external conditions
   a) strikes
   b) extreme weather conditions
   c) material non-availability

OTHER:

* 1) Timing of change - is a combination of organizational interaction and external conditions (thus the reason for the symbol used in the diagram).

*Note: These factors generally affect only the level of significance of changes and not the characteristics of changes.

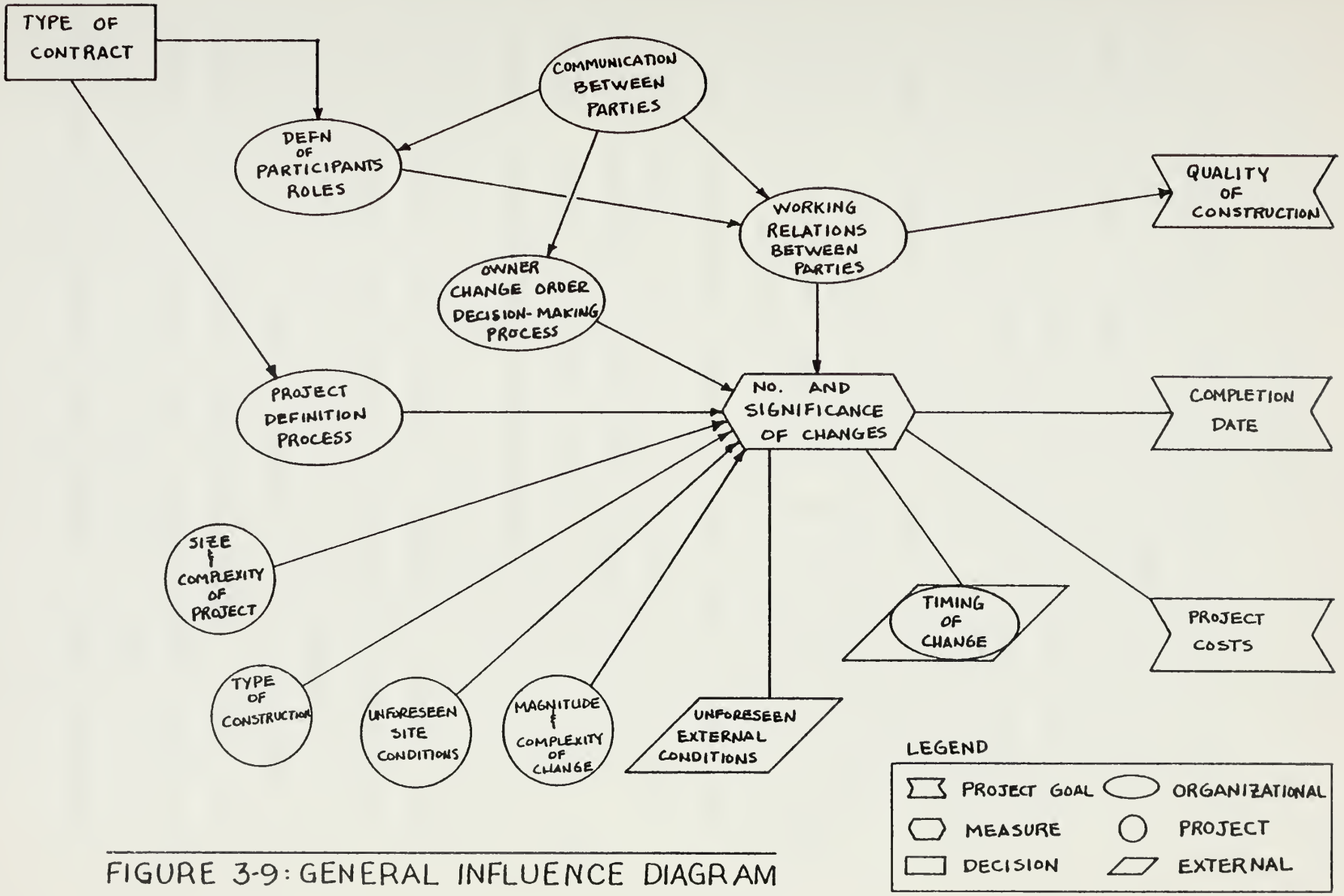

FIGURE 3-9: GENERAL INFLUENCE DIAGRAM

CONCLUSION

Although change orders are the focus of this research, they are merely a means of examining the contracting process. Change orders are an end result of this process and an appreciation for them and their significance cannot be developed apart from the context in which they occurred. For this reason it can be deceptive to compare numbers and types of change orders between projects. This research revealed that physical characteristics of changes themselves, do not offer much insight into improved management techniques. The critical factors are the organizations involved, their roles as described in the contract, their roles as perceived by each party and the interaction between them through the project process. There are several reasons for this. First, the standardization of construction materials and building components make the physical characteristics of a project well defined and fairly stable. Secondly, external conditions are beyond the control of the project participants for the most part and as a result, prior preparation cannot fully eliminate them. Therefore, each party generally accepts that unforeseen conditions are part of the risks involved in construction work. Organizational aspects on the other hand, are usually the cause of major disputes and disagreements between the parties. While the dispute

may center on a physical characteristic or external condition, the reason for the disagreement is basically a result of organizational interaction. Most often a breakdown in communication occurs, which results in the role or responsibility of a specific party not being well defined, or not being properly fulfilled. These organizational factors not only cause a lot of project changes, but also magnify the impact of changes that are the result of other factors. With these points in mind Chapter 4 will examine the nature of the characteristics of changes as observed in this research.

CHAPTER 4

REVIEW OF THE DATA

INTRODUCTION

In Chapter 3 the significant factors that contributed to major changes on the six projects examined were discussed. At the outset of this research, the objective was to identify key characteristics of changes that could be used in a predictive fashion, to forecast when a change would be of major impact on a project. The conclusion, however, and very logical in retrospect, is that changes are an end result of other project influences. These factors, as discussed in Chapter 3, include organizational characteristics, project characteristics and external conditions.

Certain characteristics of changes were consistent over different dimensions of the project. The dimensions over which these consistencies were observed included within organizations (i.e. M.I.T. and the Navy), within project type (facility) and some were observed to be consistent on all the projects. To understand why this is true a more complete understanding of the two organizations involved and their objectives is required.

ORGANIZATIONAL DESCRIPTION OF U.S. NAVY

The U.S. Navy is a large bureaucratic organization. The responsibility for project management of their multi-million dollar military construction program is assigned to the Naval Facilities Engineering Command (NAVFAC). Within NAVFAC, regional areas of responsibility have been assigned to the Engineering Field Divisions (EFDs), which are responsible for project program development and detailed design. They employ a staff of architects and engineers that perform full design services, when a project is designed in-house, and review plans and specifications submitted by the architectural firm, when a contract for design services is utilized. The task of construction project management is assigned to field offices referred to as Resident Officer in Charge of Construction (ROICC) offices, that report to the EFDs. The ROICC office is staffed with contract administrators who serve as the owner's representative on the project and a team of inspectors who ensure the project is being built in accordance with the plans and specifications. Included at all levels of the organization are both military and civilian employees. The military personnel are transferred every two years in most cases, while the civilian employees are fairly stable.

The project definition process in the Navy incorpo-

rates input from a number of different organizational levels. The project program includes service wide objectives of national defense, the user specified needs required to perform their function, and the indigenous requirements dictated by the project's locale. Strategic planning determines the facility's regional location, while station master plans and site conditions determine the specific location. User requirements are input directly by the customer organization and through the use of standard criteria developed for different types of facilities which have been established based on past experience. The EFDs are expected to include all these considerations, together with budget constraints, in the preparation of contract documents.

Once the plans and specifications are complete, the EFD usually prepares the bid documents, then the ROICC office advertises the project and accepts bids. In almost all cases federal projects are competitively bid on the basis of a lump sum contract. The contract is awarded to the lowest qualified bidder and is administered in accordance with the Armed Services Procurement Regulation (ASPR). There are requirements for a high degree of accountability in federal construction, because the expenditure of public monies is involved. This places a greater administrative burden on contract administrators

to keep detailed and accurate records that provide documentation on all changes to the contract, negotiations with the contractor and final settlement.

When a change is contemplated in military construction, there are two requirements that must be met. First, it must be within the original scope of the project and secondly, it must be required to provide a "complete and usable facility." Proposed changes that do not meet these requirements must be approved above the field office level; in this manner unnecessary changes are screened out. If the change meets the prerequisites, the ROICC office asks the contractor to submit a proposal giving the cost to complete the work and any impact on time. A separate government estimate is prepared to assess the reasonableness of the proposal, then a final settlement for cost and time is negotiated between the contractor and contract administrator. The terms of the agreed change are submitted to the EFD for preparation of a formal change order document, which is signed first by the contractor and then by the EFD. At that time additional funds are committed to the project.

The data gathered for the Navy projects examined in this research came from review of the project files maintained in the appropriate ROICC office and through discussions with the project managers. The project

managers for all the jobs reviewed were civil service employees who had been assigned throughout the duration of the project.

ORGANIZATIONAL DESCRIPTION OF M.I.T.

M.I.T. is also a large, bureaucratic organization, however, it is not as large as the U.S. Navy and is centrally located on the campus in Cambridge, Massachusetts. The responsibility for construction and maintenance of the Institute's facilities falls under the direction of the Department of Physical Plant. Within this department Architecture, Engineering and Construction Services (AE&CS) is assigned the task of developing and managing new construction projects. They employ a small staff of architects and engineers who are responsible for the preparation of the project program that is submitted to the architect to describe the basic project requirements, and for representing the owner during construction contract administration.

At the beginning of a project an individual is assigned from AE&CS to develop the project program, which defines the needs and objectives of the user, along with other basic requirements of the facility. A user representative is designated by the customer organization (school, research group, etc.) to coordinate the input

of information provided to AE&CS. A great deal of emphasis is placed on providing for the specific requests of the faculty and staff, in order to tailor the working environment to their individual needs. Once the project objectives have been determined and the program description completed, an outside architectural firm is retained to design the building.

The project team consisting of the outside architect and a representative from AE&CS, the user and engineering meet periodically throughout the design process to review progress and ensure the design meets the owner's requirements. The Building Committee which includes the President, Director of Physical Plant, Head of Architecture, Engineering and Construction Services and other key personnel, is convened to grant final approval on new capital projects and establish budgetary constraints.

In the case of a traditional contract, the architect prepares bid documents after final approval of the plans and specifications has been given. Then AE&CS receives bids and awards the contract to the lowest qualified bidder. Under fast track scheduling, a contractor is selected earlier in the process to initiate construction and advise on construction techniques. M.I.T. is not restricted to the use of specific types of contracts and therefore utilizes the contract that appears to be most

appropriate for the situation. Consideration of market competition, time to construct and other significant factors are considered in the selection of contract type.

Once construction begins, M.I.T. relies on the outside architect to administer the contract in a conventional manner. The architect is responsible for processing requisitions for payment from the contractor, reviewing shop drawings, negotiating change orders and periodic inspection of the work. A project manager, assigned by AE&CS, acts as the owner's representative during the construction phase. In the event of a change order, the architect requests a proposal from the contractor (when the owner is the initiator), reviews the contractor's proposal, negotiates the cost and time involved and then submits the change order to the owner for approval. In this capacity the architect functions as the owner's agent during construction.

The data for the M.I.T. projects was gathered from the owner's project files maintained in the AE&CS office. An interview was held with each of the owner's project managers for the projects reviewed. On the Health Services building an interview was also held with one of the contractor's project managers.

COMPARISON OF NAVY AND M.I.T.

In many ways the Navy and M.I.T. are similar organizations. Both are large and bureaucratic in structure, with a specific sub-section designated to manage the construction. Since they are both non-profit, their monetary goals differ somewhat from profit motivated firms. As a result of the variations in objectives and philosophies, however, there are four major differences between the two organizations that differentiate their construction programs. These are the project definition process, the role of the architect, the types of contracts utilized, and the change order decision-making process. Each group has evolved an efficient and professional approach to planning and management of construction, that is well suited to the needs of the individual organization. The major differences will be discussed in relationship to their resulting impact on the project. By doing this a greater appreciation for organizational characteristics and their resulting effect on construction can be developed. Some possible suggestions for improvement will also be proposed for consideration.

The project development process is more responsive to individual user requests at M.I.T. There are several significant reasons for this. The U.S. Navy, as a governmental agency, is responsible for the prudent and frugal

use of public monies. This mandates the inclusion of only essential requirements to support the building's function and provide for the well being of its occupants. Also, since military personnel are assigned to a particular billet for a relatively short period of time, usually 2-4 years, the facilities are designed for general use and not to suit the personal tastes of individuals. In addition, the size and diversity of the Navy and its resulting structure are not conducive to adapting to individual requests.

M.I.T. on the other hand, faces stiff competition in recruiting highly qualified personnel. They feel that offering a working environment that is tailored to the individual's preferences is an incentive that will attract more qualified employees. For this reason, the additional cost of construction that results from changes initiated by customer requests, is considered worthwhile. M.I.T. also has a central office that is responsible for the construction program throughout the institution. Since they are smaller and carry a project from inception to completion, they are more suited to respond to customer requests.

The role of the architect differs radically between these two institutions. The Navy limits the role of the architect to providing design services. After the drawings

and specifications are completed, the architect is only contacted in the event of a major design error or omission. M.I.T., however, relies on the architect not only to design the project, but also to administer the contract and inspect the work. These two approaches lead to a major difference in the relationship between the owner, architect and contractor, as well as the different project management organizations. Under the Navy's approach, there are direct lines of communication established between the owner and both the architect and the contractor. For M.I.T., however, the architect serves as the link between the owner and the contractor. This results in a difference between the direct control the owner exercises over the construction of the project. The Navy negotiates directly with the contractor, while M.I.T. works through the architect. These two relationships are shown in Figure 4-1. The increased responsibilities assigned to the architect under the M.I.T. philosophy,

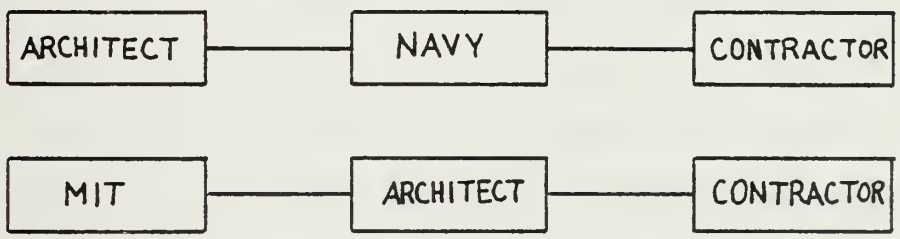

FIGURE 4-1: LINES OF COMMUNICATION UNDER CONTRACTING PHILOSOPHIES OF U.S. NAVY AND M.I.T.

allows the university to maintain a smaller project management organization. The Navy, in addition to the project managers maintained by M.I.T., must also have inspectors to ensure quality control. Thus the cost of architectural services would be higher for M.I.T., but overhead expenses would be greater for the Navy.

The third major difference in project management between M.I.T. and the Navy is the types of construction contracts each one utilizes. The Navy is restricted to the use of competitively bid contracts by federal regulations. This is to discourage favoritism in the selection of contractors. In the majority of cases the Navy uses lump sum contracts, while in some special situations unit-price contracts are utilized. All three Navy projects examined in this research used lump sum contracts. M.I.T. is not restricted to the use of particular types of contracts and can therefore select the contract that best suits the situation. Of the three M.I.T. projects examined, each one was accomplished under a different contractual arrangement. E-51 used a lump sum contract, Next House used a guaranteed maximum price contract with a design-build team and HSTM used a guaranteed maximum price with the contractor under a fast track schedule. A summary of contract types is shown in Table 4-1. This points out a significant difference between the Navy's

contractual relationships and those of M.I.T. The roles of the owner, architect and the contractor remain consistent on all the Navy's projects. This allows standard procedures for contract administration and record keeping to be established for the Navy. The result is a high degree of accountability as required by federal regulations and increased standardization, which reduces the disruptions caused by the transfer of personnel. It should also be noted that the regulations in federal contracting create more formal relationships between the parties to the contract. This was especially evident in the negotiation of change orders, which had specific steps to be followed and documentation that had to be maintained for the Navy projects. The process on M.I.T. projects appeared to follow the same general steps, but were handled more informally (this is difficult to ascertain because the architect negotiated change orders for M.I.T.). For M.I.T. the roles of the owner, architect and contractor may vary on different projects. The owner needs to be aware of this and the effect it has on the project. Under different contracts, the owner may need to adjust the amount and type of control exercised individually over the architect and contractor. The increased flexibility available to M.I.T. in contractual agreements creates a greater opportunity for cost and time savings in construction, when properly employed.

ORGANIZATION	FACILITY		
	CLASSROOM	DORMITORY	HOSPITAL
MIT	LUMP SUM	GMP (DESIGN-BUILD)	GMP (CONTRACTOR FAST TRACK)
	RENOVATION	NEW CONSTRUCTION	NEW CONSTRUCTION
USN	LUMP SUM	LUMP SUM	LUMP SUM
	NEW CONSTRUCTION	NEW CONSTRUCTION	NEW CONSTRUCTION

TABLE 4-1 : SUMMARY OF PROJECT CHARACTERISTICS (TYPE OF CONTRACT AND TYPE OF CONSTRUCTION)

The last major organizational difference between M.I.T. and the Navy is the decision-making process for change orders. As described earlier, the Navy has strict requirements on allowable changes to ensure that only necessary changes are made. These regulations governing change order decisions, establish a consistency in the process which to an extent predetermines the decision. M.I.T. on the other hand assesses each proposed change, with the major contraints being those of cost and time to complete. This process requires a greater amount of management effort on a daily basis, but also provides greater leeway in making modifications to the facility.

The project characteristics of the facilities compared between M.I.T. and the Navy were very similar. Three project pairs were selected, two classroom buildings, two dormitories and two hospitals. The function and operations of paired facilities were very similar, as was the magnitude of project pairs in terms of costs. All the jobs were new construction, with the exception of the classroom building for M.I.T. (E-51), which was renovation. The similarity of the projects compared between M.I.T. and the Navy, along with the variety in types of facilities, establishes a basis for comparing change orders between owner organizations and facility types. Table 4-1 summarizes the type of facility and type of construction

for each of the six projects.

External conditions are similar for most construction, in that they are unpredictable to a large degree. Conditions within geographic regions such as weather and labor relations vary and may affect the type of construction and facility function differently. For the purposes of this analysis however, they will be considered random occurrences since the owner and the contractor often have less choice and control over these factors.

REVIEW OF THE DATA

As the data collected on the six projects is examined, it should be remembered that change orders are an end product of the project process. They represent an agreement that is reached between the owner and the contractor, which modifies or clarifies the original construction contract. The changes investigated on the six projects reviewed, represented an agreement which modified the original contract in one of three distinct ways. The first was a deviation from the original plan, which altered the job requirements as initially stated. The second was an expansion or clarification to the original plan when something had been omitted, misunderstood or not fully defined at the time of the agreement. The third was an accounting procedure to reconcile allowances estab-

lished for budgetary control.

Since the parties involved in a project have differing goals and objectives, and since the terms of a contract are not always interpreted the same by all the participants, there is an inherent element of disagreement in the change order process. Various degrees of disagreement were observed in the changes reviewed, ranging from claims submitted by the contractor which the owner did not consider legitimate, to changes that were immediately accepted by the owner after the contractor's initial proposal. The negotiation process, elements that need to be considered and the compromise involved in the resolution of change orders is a whole different area of study which has not been addressed here.

Reviewing information contained in Table 4-2, there are several observations that can be made concerning the projects reviewed. First, the construction phase for the M.I.T. projects was consistently shorter than that for the Navy projects. From this observation, it appears that M.I.T. built its facilities in a shorter period of time than the Navy. This does not account for any differences in the size, complexity and quality of construction between the projects compared. The reason for the shorter duration of construction on M.I.T. projects may be explained by the use of fast track scheduling. Reduced

FACILITY	CONTRACT $ VALUE	NO. CHANGES *	$ VALUE CHANGES *	$ TOTAL *	DAYS TO CONSTRUCT ORIG. *	NO. DAYS EXTENDED +	TOTAL CONSTRUCTION TIME *
AIB	$3,857,000 $4,435,120 Δ	29	$29,590 (.77%) $34,020 Δ	$3,886,590 $4,469,140	540	9 (1.7%)	549
E-51	$3,664,937.41	75	$159,940 (4.4%)	$3,824,880	465	65 (14.0%)	530
UEQ	$7,600,000 $7,996,720 Δ	53	$119,560 (1.6%) $125,800 Δ	$7,719,560 $8,122,520 Δ	600	4 (.7%)	604
NEXT HOUSE	$8,597,300	47	$539,600 (6.3%)	$9,136,900	480	15 (3.1%)	495
NRMC	$16,770,000 $19,283,620 Δ	108	$2,480,740 (14.8%) $2,852,570 Δ	$19,250,740 $22,136,190	885	610 (68.9%)	1495
HSTM	$24,835,000	278	$3,075,610 (12.4%)	$27,910,610	739	150 (20.3%)	889

* APPROXIMATE + BASED ON CONSTRUCTION TIME, NOT NEGOTIATED CHANGES

Δ ADJUSTED BY MEANS COST DATA

TABLE 4-2 : COMPARISON OF TIME & COSTS ON PROJECTS

construction time has been observed on other projects employing fast tracking techniques, such as residence halls at the University of California.[1] It also appears that the cost of construction on M.I.T. projects was higher than that of the Navy projects. This is based on a comparison of the amount paid to the contractor and excludes overhead and inspection fees. A simple adjustment in cost for project location was made using the city cost indexes from the 1980 Means Cost Data for building construction. In most cases the percentage of increase for both time and cost as a result of change orders was higher for M.I.T. projects. This is probably a result of the difference in contracting procedures, where the Navy has completed plans and specifications prior to construction, M.I.T. may begin with a general project program. In addition, the different philosophies in allowing customer changes already discussed, influences this. To get a more accurate comparison of time and costs of projects between the two organizations, the time and costs associated with the total project design and construction phase should be examined.

By comparing different categories of changes, including: reason code, initiator, type of work and influ-

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1. "Construction Management: Whirling in Evolution and in Ferment," ENR, 4 May 1972, p. 17.

encing factors, there are a number of characteristics that become evident on the six projects reviewed. It should be noted that it is somewhat deceptive to present a comparison of changes as summarized in Tables 4-3, 4-5, 4-6, and 4-8, because of some of the possible biases discussed in Chapter 2. The major ones affecting this data will be reviewed here. First, the framework of categorizing changes developed through the data gathering process and as a result the perspective from which change orders were viewed altered as research progressed through the projects. At the end, the data from previous projects was reviewed and adapted to the final framework. In a number of cases changes may have fallen into more than one category; if there appeared to be multiple categories that were dominant, the change was listed under each one. Also, the number of changes on a project was somewhat arbitrary as a result of differences between project managers in the way additional work was divided into separate changes. These factors may have led to inconsistencies in the categorization process. In addition, there was no precise definition for each of the categories utilized. This, along with the subjective nature of choosing the category as interpreted by the different project managers, led to variation in data consistency. These biases do not invalidate the conclusions drawn from the data, because the significant trends discussed in the remainder

of this chapter would not change as a result of minor variations in the data. With this in mind the data results will be discussed.

Looking at Table 4-3 there are several trends that can be observed. First, the design errors and omissions were generally a significant reason for change, with only the design-build project having an insignificant number of design errors and omissions. For the Navy projects this was a much more dominant characteristic, with over one-half of the changes falling into this category. The reason for this is the use of conventional contracts, in which design drawings and specifications are completed prior to the beginning of construction. The opportunity for contractor suggested improvements in this situation is reduced and then changes are required to correct errors and omissions in the design, many of which are minor in nature. More extensive site investigation and review of plans and specifications would reduce changes in this category, however, the resulting cost may not offset the gain. In a well run fast track project there is a greater amount of design review built into the process.

Unforeseen conditions were encountered on all the projects except for one. While these changes are not often a large percentage, they many times have a significant impact on the project, because they are unexpected

REASON FOR CHANGE	AIB		E-51		UEQ		NEXT HOUSE		NRMC		HSTM	
	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%
DESIGN ERRORS & OMISSIONS	19	66	13	17	28	53	2	4	55	51	34	12
UNFORESEEN CONDITIONS	1	3	18	24	3	6			9	8	2	1
CUSTOMER REQUESTS	1	3	24	32	7	13	26	55	14	13	177	64
OPERATIONAL CHANGE			2	3			1	2	9	8		
FUNCTIONAL CHANGE	1	3	7	9			2	4	2	2		
MATERIAL SUBSTITUTION	7	24	8	11	5	9	3	6	10	9	14	5
COST SAVINGS			2	3			4	8	2	2	13	5
IMPROVEMENT					6	11			3	3		
CONTRACTOR CONVENIENCE					4	8						
CLAIMS BY CONTRACTOR	7 *		4	5			7	15	**		15	5
DESIGN OPTION							3	6				
ALLOWANCE ITEMS											9	3
MISCELLANEOUS									4	4	23	8
TOTAL CHANGES	29		75		53		47		108		278	

* INCLUDED IN OTHER PRIMARY CATEGORIES

** A SINGLE SETTLEMENT WAS MADE AT THE END OF THE PROJECT RESULTING IN THE RESOLUTION OF ALL CLAIMS.

TABLE 4-3: DATA ON REASON FOR CHANGE

and beyond the control of the parties involved. Unforeseen conditions are random occurrences almost by definition and can not be eliminated even by prudent management. As discussed in Chapter 3 under the E-51 project, unforeseen conditons are a major characteristic of renovation work. The best remedy for unforeseen conditions is rapid resolution of the problem, which requires good working relations and open channels of communication.

Customer requests were a major category of changes on the M.I.T. projects, but did not have a significant impact on the Navy projects. This is a result of the difference in philosophies and operations between the two organizations, which has already been discussed. It should also be noted that functional and operational changes are closely associated with customer requests and the distinction between them is often a matter of definition and not one of substance. In the case of the Navy hospital in Orlando, the impact of the EMCS being added (a functional change) was similar to the effect of customer requests on M.I.T.'s projects. Looking at the percentage of changes in these three categories (customer requests, operational change and functional change) there is still a radical difference between M.I.T. and the Navy because of their individual policies.

The source of origination of changes (either owner or contractor) also indicates certain characteristics of the project. Table 4-4 shows the typical originator of changes as observed on the projects examined, identified according to the reason for the change. The generally observed impact on the project resulting from the change is also indicated, (-) means negative impact, (+) means positive impact. Negative impact changes generally require management attention and increase the costs and time associated with the project. Positive impact changes, although they require management attention, generally reduce the costs and time associated with the project, or prevent even greater costs and time increases as the result of the change.

Looking at Table 4-5A, it is observed that for all the M.I.T. projects there were more owner initiated changes than contractor initiated changes. For the Navy projects there were more contractor initiated changes than owner initiated changes, except on the hospital project. The fact that M.I.T. initiates a higher percentage of changes on their projects than the Navy, goes back to the difference in operating procedures between the two organizations; but it also appears that the greater the complexity of the work (as in the case of the hospitals), the more owner (or architect) initiated changes there

REASON FOR CHANGE	IMPACT	ORIGINATOR		
		OWNER	CONTRACTOR	EITHER
DESIGN ERRORS & OMISSIONS	−			X
UNFORESEEN CONDITIONS	−			X
CUSTOMER REQUESTS	−	X		
OPERATIONAL CHANGE	?	X		
FUNCTIONAL CHANGE	?	X		
MATERIAL SUBSTITUTION	+			X
COST SAVINGS	+			X
IMPROVEMENT	+			X
CONTRACTOR CONVENIENCE	+		X	
CLAIMS BY CONTRACTOR	−		X	
DESIGN OPTION	?	X		
ALLOWANCE ITEMS	?	X		
MISCELLANEOUS	?			X

TABLE 4-4 : TYPICAL SOURCE OF ORIGINATION OF CHANGES BY REASON FOR CHANGE

B. CHANGES INITIATED BY EITHER	A1B		E-51		UEQ		NEXT HOUSE		NRMC		HSTM	
REASON FOR CHANGE / ORIGINATOR	O	C	O	C	O	C	O	C	O	C	O	C
DESIGN ERRORS & OMISSIONS (-)	8	11	1	12	5	23	2	ø	25	30	26	8
UNFORESEEN CONDITIONS (-)	ø	1	2	16	1	2			1	8	ø	2
MATERIAL SUBSTITUTION (+)	2	5	6	2	ø	5	1	2	6	4	11	3
COST SAVINGS (+)			2	ø			1	3	1	1	10	3
IMPROVEMENT (+)					ø	6			3	ø		
(-)	8	12	3	28	6	25	2	ø	26	38	26	10
(+)	2	5	8	2	ø	11	2	5	10	5	21	6
SUB TOTAL	10	17	11	30	6	36	4	5	36	43	47	16
A. ALL CHANGES												
(-)	9	12	27	32	13	25	18	7	40	38	203	25
(+)	2	5	8	2	ø	15	2	5	10	5	21	6
OVERALL	12	17	43	32	12	41	35	12	63	45	245	33

TABLE 4-5: DATA ON ORIGINATION OF CHANGES

will be. On categories of changes that have generally negative impact and positive impact on the project there are no consistently observed trends; however, further research in this area may reveal new insights.

In Table 4-5B, the data for changes that are not typically initiated by either the contractor or owner is shown. Although not conclusive, there seems to be a trend that the contractor originates most of the changes resulting from design errors and omissions. This is reasonable since the contractor will usually be the one who recognizes something cannot be constructed as prescribed. The same principle holds true for changes resulting from unforeseen conditions. The other categories of changes do not have any significant trends, perhaps because there were not a sufficient number of instances observed.

By categorizing changes according to the type of work (using the Construction Specifications Institute classification), there are some general observations that can be made. Table 4-6 presents the data collected by type of work. There was a substantial degree of consistency observed in the type of work, changes fell into. The areas of electrical and mechanical work contributed to a large percentage of the changes on all the projects. Since electrical and mechanical services are integrally

TYPE OF WORK (CSI CATEGORIES)	AIB		E-51		UEQ		NEXT HOUSE		NRMC		HSTM	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
GENERAL			2	3							1	ø
SITE	2	7	5	7	8	15	3	6	6	6	11	4
CONCRETE	1	3			3	6	2	4			1	ø
MASONRY	1	3	2	3	2	4			1	1	19	7
METAL			5	7			1	2	6	6	12	4
CARPENTRY			8	11	3	6	5	11	9	8	22	8
MOISTURE PROT.	1	3	2	3	1	2			1	1	6	2
DOORS, WINDOWS, GLASS	4	14	8	11	4	8	3	6	3	3	17	6
FINISH	2	7	6	8	4	8	7	15	3	3	37	13
SPECIALTY			1	1	2	4	1	2			8	3
EQUIPMENT			3	4			4	9	7	7	9	3
FURNISHINGS			1	1	1	2					2	1
SPECIAL CONSTR.												
CONVEYING SYS.			1	1			2	4	1	1	4	1
MECHANICAL	5	17	13	17	19	36	6	13	27	25	57	21
ELECTRICAL	12	41	15	20	6	11	15	32	47	44	52	19
MULTIPLE / MISC	1	3	4	5			4	9			39	14
TOTAL	29		75		53		47		108		278	

TABLE 4-6: DATA ON CHANGES BY TYPE OF WORK

Thesis
G2635
c.1

George

199480

Change orders - identifying key factors and their impact on construction projects.

Thesis
G2635
c.1

George

199480

Change orders - identifying key factors and their impact on construction projects.

thesG2635
Change orders :
3 2768 002 02586 8
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